PROCEEDINGS:
COMPOSTING OF ORGANIC WASTES SEMINAR
OCTOBER 24, 1984

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OCTOBER 24, 1984

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Ontario Ministry of the Environment

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PROCEEDINGS

COMPOSTING OF ORGANIC WASTES SEMINAR

Held at the

Ontario Ministry of Health Laboratories

October 24, 1984

Sponsored and Organized

by

POLLUTION CONTROL ASSOCIATION OF ONTARIO

ONTARIO MINISTRY OF THE ENVIRONMENT

SCHOOL OF ENGINEERING UNIVERSITY OF GUELPH

Seminar Co-Chairmen:

Brian LeClair, The Gray Engineering Group
Jack Pos, University of Guelph

Preface

Society is placing greater demands on municipalities and regional governments for more efficient and less hazardous methods of handling and disposing of solid wastes. There is increasing objection to more and larger landfills and the environmental problems they produce. Budgetary constraints require that cost effective solutions be found.

Composting is one of several high technology options available either singly or in combination with other resource recovery systems that may not only be cost effective, but can also produce a saleable product to offset the processing cost and also reduce the problems of environmental pollution.

This Seminar was designed to give an overview' of the subject with specific reference to the type and amount of organic wastes available and the potential for composting in Ontario. The paper on Health Aspects discusses the large variety of micro-organisms, some of which could present a potential health hazard to workers at the plant if proper control and production procedures are not observed.

The need for process control and operating procedures is emphasized under 'Guidelines and General Requirements' to ensure a safe and quality controlled product. The discussion on 'Alternative Processes' gives some insight into the basic high-rate process and several alternative procedures. 'Design Considerations' are concentrated on feedstock characteristics, process objectives, control of process parameters and systems design. Economic aspects include 'Marketing and Utilization .

Four case studies included the Delaware Reclamation Project serving the county of New Castle and the City of Wilmington and used shredded solid waste and sewage sludge An Agricultural Project utilizing animal manure from a commercial feedlot and livestock waste from the University of Guelph. Sewage sludge was being composted from the City of Windsor Water Pollution Control Plant. Municipal refuse was separated at the Downsview Recycling Plant and the compostible fraction was processed by means of a continuous flow, automatically controlled, aerobic-thermophilic bio-reactor designed by Fairfield Service Company, Marion, Ohio.

J. Pos
November 5, 1984

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COMPOSTING IN THE 1980's:
AN INTRODUCTION AND OVERVIEW

by: R.M. Gotts[1]

COMPOSTING AS A COMPONENT OF ONTARIO'S WASTE DISPOSAL/RECOVERY PROGRAM

I would like to thank the Ontario Pollution Control Association for this opportunity to talk to you today. Before I get into composting, it would be useful and relevant to list the Waste Management Branch's current objectives relating to municipal waste disposal and material recovery. These include:

- Demonstration and assessment of technologies for resource and energy recovery;
- Development of markets for recoverable products;
- Source Separation;
- Material conservation; and
- Promotion of alternative processes to landfill.

These objectives have been clarified and brought into focus during the last decade. The Comprehensive Resource Recovery

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[1]Director, Waste Management Branch, Ontario Ministry of the Environment. Paper presented at the MOE-PCAO October 24, 1984 Seminar on "The Composting of Organic Wastes".

Programme, conceived in 1974, stemmed from the enactment of the Waste Management Act in 1970. The creation of our Experimental Plant for Resource Recovery at Downsview, in 1975, at a cost of $16 million, was part of that program. This plant has become the cornerstone of our current resource recovery philosophies, which are very evident in the "Blueprint for Waste Management in Ontario"[1]. We published this discussion document in June, 1983.

Composting is just one of several alternative processes which can help to reduce the amount of waste requiring disposal by landfilling. Extending the life of approved Ontario landfills will provide additional time for the location of new landfills and the development of alternative solutions to waste management problems.

PROPERTIES AND VALUE OF COMPOST

Compost is a natural organic product similar to peat. Like peat, it is a soil conditioner rather than a fertilizer. It contains large amounts of humus, moisture and small amounts of nitrogen, phosphorus and potash. It has a slight musty odour, and is dark in color. Its texture depends on the degree of screening and other processing.

Compost has the potential to:

- Add organic matter to soils and/or mixes;
- Increase the permeability of clay soils;
- Increase water holding capacity of sandy soils;
- Improve soil friability;
- Promote root growth.

The main use of compost then, is to amend soil properties. It is not normally considered to be a fertilizer simply because it does not usually provide enough nitrogen, phosphorus and potassium, when spread at the recommended and economical application rates, to meet crop needs in the growing season.

The term "Composting" is widely used but is often misunderstood by the general public. We define it as "the biological decomposition of organic waste materials under aerobic conditions to produce a stable humus or soil-like product".

The biochemical oxidation and decay of organic materials takes place all around us and is taken for granted. It results from microbial action on bio-degradable organic materials. Microbial action is not well understood, even though composting processes have been used for hundreds of years; it is only in recent years that serious scientific microbiological studies on composting studies have begun.

AVAILABILITY OF COMPOSTABLE MATERIALS

Figure 1, which is based on information provided by Bird and Hale[2], illustrates the average proportions of municipal Solid waste (MSW) for 25 Canadian cities. A minimum of 63% of the wastes is potentially compostable. The wastes include:

Paper - 35 to 40%; and

Putrescibles - 25 to 30%.

Each day , in Ontario, each person generates about 2 lbs. of household waste.

Waste sewage sludges, generated by sewage treatment plants in Ontario, also have potential for composting. These sludges are usually incinerated, land-filled or in some cases, stabilized and used in agriculture.

Figure 2 illustrates the methods used in Ontario for sludge disposal. Altogether about 4.6 million cubic metres of wet sludge are produced each year, which is equivalent to about 0.2 lb of dried sludge per household per day. Only 115,000 cubic metres per year are used in composting. Although Windsor is the only Ontario municipality using sludge in this way, composting processes are widely used in the eastern USA for sludge management.

Metro Toronto alone deals with some 5000 tonnes per day of M.S.W. (2500 tons of household waste) and almost 4000 m^3 of wet sludge per day. Thus, in municipalities throughout Ontario, in both built-up urban areas and in rural communities, there is no shortage of compostable organic wastes.

In addition to the organic materials available in municipal solid waste, compostable materials are also available in agricultural and food processing wastes.

For municipalities, the large amounts of solid waste and sludge often present a disposal problem. Because of the increasing shortage of environmentally approved land suitable for landfilling, municipalities are coming under pressure to find alternatives to landfilling.

The Waste Management Branch, recognizing this problem, has been deeply involved at looking at alternatives for waste management. These alternatives are embodied in the 4R's - Reduction, Reuse, Recycling and Recovery. Composting of the organic fraction in waste is one viable alternative for reducing the amount of waste requiring landfilling. At the same time composting embodies the ultimate recycling process, the conversion of organic wastes back into soil.

HISTORY OF COMPOSTING

For many centuries, farmers and gardeners used primitive methods to compost organic materials, vegetable matter, human and animal faeces, usually under anaerobic conditions, either in pits or in above-ground piles. The materials were usually dumped together, as and when they became available, in a rather haphazard fashion. The quality of the compost produced varied considerably. In many cases, it was far from pathogen-free and nitrogen concentrations were very low.

The Indore process, the grandfather of modern composting processes, described by Gotaas[3], was developed about 50 years ago in India. Straw, leaves and other bulky, relatively stable wastes were stacked in alternate layers with night-soil or animal manure, or sludges from sewage treatment. Liquor draining from the piles was recirculated into the compost.

In more recent years, the chemical and biological processes which result in waste decomposition have been studied comprehensively.

Since 1930 the number of composting plants in operation gradually increased. In the 1960s the number peaked, but composting then began to lose favour. Commercial compost then lacked credibility, primarily because markets were neither actively developed nor properly defined.

Many operations lost money because of the lack of firm markets and competition from established products such as peat moss and other soil additives. In addition, sewage sludge was not amenable to mechanical composting because of its high moisture content. The technology for sludge dewatering, was then just emerging; the dewatering options we have today were not then available. Moreover, the need for technical monitoring of the finished product with respect to heavy metals and pathogens, etc. was often not then properly appreciated.

However, the trend has now reversed. Since the late 1970's, mechanical composting concepts, equipment options and markets, etc. have begun to climb. We feel that, in Ontario, MOE's efforts have been a factor in the end-users' increased awareness that compost derived from municipal solid waste and sludge is a viable product.

PRINCIPLES OF COMPOSTING

Dead organic matter contains nitrogenous and carbonaceous materials and nutrients which decompose and can support new growth. Thus both aerobic and anaerobic processes can play roles in composting. Composting involves the synergistic and successive effects of mixed bacteria, actinomycetes and other fungi, according to variations in factors such as moisture level, temperature, pH, nutrient concentrations and oxygen

availability. These organisms and their effects, and pathogen inactivation will be discussed in a subsequent paper.

In aerobic processes, when organic materials decompose to form ammonia, nitrates, carbon dioxide, water and nitrogeneous gases, they release heat. When the compost temperature reaches 45°C, thermophilic or heat-loving bacteria begin to replace the mesophilic bacteria which started the decomposition process. In composting processes, high temperatures are of paramount importance. Heat loss can be reduced by the insulating effects of other materials. Pathogenic bacteria, protozoa and eggs are inactivated and many weed seeds are destroyed. Modern commercial composting operations usually embody aerobic thermophilic processes in which temperatures of 65°C are maintained for about 3 days.

In anaerobic processes, fermentation processes result in the formation of carbon dioxide; organic acids and acid carbonates. Hydrogen sulfide and sulphurous components such as mercaptans also result from anaerobic processes. However, much less heat is released and, as a result, many pathogenic organisms are not inactivated. Therefore, anaerobic processes are rarely used in commercial composting.

PRESENT-DAY PROCESSES

In small composting operations, farmers and rural householders use composting processes which are primarily aerobic

in nature but which do embody some anaerobic elements. With care, such processes may be safely used to produce materials which can enrich and condition farm and garden soils. A Ministry of the Environment Leaflet[4] provides further information.

For convenience, traditional and modern-day composting processes are usually classified as follows:

- Unconfined Processes
  - Windrow
  - Aerated static pile
    - Individual pile
    - Extended pile
- Confined Processes

Even with these classifications, each composting operation is usually unique. However, all commercial processes can have common elements:

- Bulking agents, which can be recovered, may be added to control moisture and porosity. These are generally used only in sludge composting.

- A temperature of at least 65°C for an extended period to inactivate pathogenic organisms;

- Compost storage, after pathogen inactivation, to further stabilize it before use; and

- Air drying

SEWAGE SLUDGE AS A COMPOSTABLE MATERIAL

Sewage sludges, used with recoverable bulking agents such as bark or wood chips and shredded tires, or in combination with selected wastes separated either at source or during the collection- disposal process, have excellent potential for composting.

Significant sludge composting research was conducted by U.S. Dept. of Agriculture at Beltsville, Maryland, U.S.A. This well documented work[5,6], has resulted in several full scale municipal composting operations using the aeration/ windrow process. Such processes are well demonstrated by the City of Windsor operation at the West Windsor WPCP Centre. A paper on this is to be presented later in the seminar.

Modern technological advances have further resulted in partially closed mechanical systems, which incorporate the Beltsville research. Many communities now compost sludge using combined mechanical/windrow systems. Installations at Plattsburg, Bangor, Durham, Cape May, Miami, Philadelphia and Wilmington provide examples of full scale operations.

Sewage sludge can either be composted on its own, or co-composted with municipal solid waste. In some locations, the implementation of Ontario's "Guidelines for Sewage Sludge Utilization on Agricultural Lands"[7] has resulted in some high-metal sludges becoming unsuitable for use in agriculture. This may open up some opportunities for co-composting. Municipalities are now more aware that landfilling fluid sludge can be difficult and costly. When wastes and sludges are mixed, an acceptable compost may be attainable. The proportions of refuse-sludge mixes are not critical; they can often be adjusted to optimize use of the material presenting the greatest local disposal problem. Many types of mixing equipment are currently available.

Sludge moisture content can now be adjusted, by a wide variety of dewatering processes. The moisture content of municipal solid waste (MSW) is normally less than that required for composting; water or sludge may be added to achieve the proper moisture content.

In summary, entrepeneurs and others may now be able to revive the concept of sludge-refuse co-composting; in the next few years we may see many such projects. In fact, in other jurisdictions, many new composting facilities have been constructed and several existing composting facilities have been extended. After closure of a major landfill, a New Jersey

official was recently reported[8] as saying: "We are scrambling to bring new sludge composting facilities on line in New Jersey". In addition a new resource recovery operation in Wilmington, Delaware, now being commissioned, will incorporate 1000 Tons of MSW and 700 Tons of sludge each day. It will produce a substantial amount of compost. Similarly, in Washington, D.C., composting facilities are being enlarged and another facility in nearby Maryland is also proposed.

MOISTURE CONTROL AND SLUDGE DEWATERING

Monitoring requirements are to be discussed in a later paper. However, I would like to comment on the impacts of moisture in composting and on sludge dewatering processes.

Moisture content is perhaps the most critical element in compost production quality control. High decomposition rates are required to achieve the temperatures necessary for pathogen inactivation. Decomposition can occur when moisture content is about 85%, but lower moisture concentrations are necessary for commercial operations. Maximum decomposition rates occur if it is in the range of 50% to 60%.

Because the use of high-moisture sewage sludges can affect composting, some sludge dewatering is usually essential. The extent of the dewatering will be dictated by the moisture contents of the other materials to be composted and of the

bulking agent, if one is used. The capability of the dewatering equipment varies according to the type of equipment, the intended range of its removal capacity, the type of sludge and the specific sludge which is to be dewatered. The U.S. EPA reports[9] the expected dewatering capabilities of several types of equipment. The ranges for belt press equipment, are shown in Figure 3.

Belt press equipment then, can achieve for waste activated sludge - 15-24% solids, for a 1:1 mixture of WAS and raw primary sludge - 20-30% solids, for raw primary sludge - 28-40% solids and for a mixture of thermally conditioned primary and waste activated sludges - 38-50%.

Other equipment, such as filter presses, diaphragm filter presses, solid bowl centrifuges, basket centrifuges, vacuum filters, sludge concentrators and dual cell gravity units, also exhibit wide operating ranges.

Obviously then, dewatering capability is very strongly dependent not only on the type of equipment, but also on the type of sludge and the characteristics of the individual sludge to be dewatered.

Recent advances in mechanical composting equipment, alternative composting processes, contemporary composting ventures, health monitoring requirements and proposals for provincial guidelines for "Composting Production, Quality and

Use"[10], as well as other provincial and federal requirements should be reviewed by proponents of composting. Other speakers will address these topics. We feel, and I hope you will agree, that well- identified government requirements are essential if proper (environmental) control is to be achieved in practice. These controls will provide the framework within which compost operations will function.

Only composts considered cured (inactive), with low concentrations of metals and pathogens, should be available for distribution to the public. Permissible compost uses should be related to the degree to which the compost meets the permissible parameters identified.

ECONOMICS OF COMPOSTING

The most significant factor in the viability of compost production is the availability of markets. Assessment of markets is, for the proponent, a pre-requisite. Unless markets are there, it is absolutely certain that composting operations will not be economic. In developing markets, it must be recognized that composting is not normally considered a pretreatment to disposal, but as a treatment to permit utilization.

Estimates and balance sheets should record full costs and revenues, and reflect the cost savings attainable when other disposal methods and facilities are not required. For example, when wastes are recovered and the need for their

disposal does not arise, the cost of disposal, or a portion of it should be credited to the waste recovery operations.

Some municipalities may not have concluded that composting is viable because their bookkeeping does not include all costs. Not only may they charge equipment and manpower costs against other activities but, more significantly, the landfill capital costs, if included, may often be based on original costs at the time when the landfill was established, rather than on current or future site replacement costs.

In summary, accurate and complete cost-assessment are required for:

- Composting
- Other waste utilization processes
- Disposal.

The absence of clearly defined markets may not preclude a composting operation. In the case of a recent landfilling proposal, our review pointed out that including compost in final cover could reduce the amount of waste landfilled and so extend site life by up to two years. If compost became available to improve the quality of the final cover, some of it could be diverted and offered to other potential users. This might permit markets to be developed.

MARKET INVESTIGATION

Composting offers many benefits. It is often avoided as a waste management method because of apprehensions that it would be too costly, that large profits are an essential or that it is an unpleasant, odorous operation. These apprehensions must be dispelled.

Often there are opportunities for compost use on municipally-owned land. These include final cover at landfills, compost application on municipal gardens, public parks, tennis courts, lawn bowling facilities, school and public playing fields, grassed areas within road allowances in subdivisions and the like. Overall costs might well be less than when materials from other sources are used. In the private sector, potential uses can include landscaping ventures such as residential, commercial and industrial sub-divisions and land reclamation. In some locations, farmers need compost as a soil conditioner, or to replace humus in those agricultural soils which have low concentrations of organic matter. It may be possible to sell compost when such needs exist.

Compost from municipal operations is generally sold in bulk form. It may, however, command a much higher price if it is bagged for sale, particularly if it has been screened and additional nutrients have been added.

In the long term, the public must be assured that there are adequate controls over compost production and uses; unfounded public concern and opposition will then disappear. Giveaway programs may initially be necessary to stimulate market development, but we are confident that, ultimately, compost will become a saleable commodity, and that its selling price will reflect its value and benefits. This approach has been used for compost produced at the Ministry's Experimental Plant.

Market and public acceptance of quality compost as a usable product has already been demonstrated. Our Ministry, municipalities and entrepreneurs now face the challenge to develop the compost waste management option and place it in its proper environmental perspective.

REFERENCES

1. Blueprint for Waste Management in Ontario. Ontario Ministry of the Environment, June, 1983.

2. Municipal Refuse Statistics for Canadian Communities of Over 100,000 (1976-1977) Waste Management Branch, Environmental Protection Service, Environment Canada. Prepared by Bird & Hale Ltd., Clarke, Perzko & Associates Ltd., L.S. Love & Associates (Canada) Ltd.

3. Composting. Harold B. Gotaas. Pub. World Health Organization 1956.

4. Be a Good Sort to Your Garden, Ministry of the Environment

5. Process Design Manual for Sludge Treatment and Disposal (EPA-625/1-79-011) September, 1969, U.S. EPA.

6. Sludge Treatment and Disposal: Volume 2 - Disposal (EPA-625/4-78-012), October, 1978.

7. Guidelines for Sewage Sludge Utilization on Agricultural Lands. Ontario Ministry of Environment and Agriculture and Food, 1981. Revision pending.

8. Sludge Newsletter V9; No. 15 - June 16, 1984.

9. Design Manual: Dewatering Municipal Wastewater sludges (EPA-625/1-82-014). October, 1982, U.S. EPA.

10. Draft Interim Guidelines for Compost Production, Quality and End Use. Ontario Ministry of the Environment, (Not published)

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FIGURE 1

CANADIAN WASTES FOR 25 CITIES					
	% WEIGHT	% WATER		% WEIGHT	% WATER
PAPER	36.5	2.5	LUMBER	4.2	1.1
GLASS	6.6	0.7	PUTRESC	27.6	2.7
FERROUS	6.1	0.7	TEXTILES	4.3	0.5
NON-FERROUS	0.6	0.1	YARD WASTE	6.1	2.1
PLASTIC	4.7	0.3	FINE MATERIAL	1.2	0.4
CERAMICS	1.8	0.8	PETRO-CHEM.	0.6	0.5

NOTE: AFTER BIRD & HALE

FIGURE 2

ONTARIO SLUDGE DISPOSAL METHODS

METHOD	% OF SLUDGE	% OF WPCP's
AGRICULTURE	34	55
INCINERATION	33	3
LANDFILL	26	20
COMPOST	3	1
MINE TAILINGS	2	9
OTHER	2	12

FIGURE 3

DEWATERING CAPABILITY OF
BELT PRESS EQUIPMENT

SLUDGE TYPE	% SOLIDS IN DEWATERED SLUDGE CAKE
RAW WASTE ACTIVATED	15 - 24
RAW PRIMARY + RAW WASTE ACTIVATED (1:1)	20 - 30
RAW PRIMARY	28 - 40
TERM. CONDITITIONED PRIMARY AND WASTE ACTIVATED	38 - 50

BASED ON EPA PROCESS DESIGN MANUAL FOR DEWATERING MUNICIPAL WASTEWATER SLUDGES (EPA-625/1-82-014; OCTOBER 1982)

PATHOGENIC ORGANISMS IN COMPOST MATERIALS

by

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1984.

PATHOGENIC ORGANISMS IN COMPOST

MATERIALS

INTRODUCTION

The process of composting is considered to be a valuable one in the field of resource recovery. The end product is a humus-like material used as a soil amendment for a variety of agricultural and domestic purposes. The materials used in the production of compost, usually sewage sludge in combination with some form of "bulking" material such as wood chips or municipal garbage, contain a variety of microorganisms some of which may be pathogenic to man or animals.

From a public health point of view, it is necessary to ensure that:

a) workers at composting sites are protected from hazard due to these pathogens

b) the finished product does not constitute a hazard to man or animals.

Sources of Pathogenic Microorganisms in Compost Materials

1. Sewage sludge. The major source of human pathogenic microorganisms in compost is sewage sludge. Since a large part of sewage sludge is derived from human feces, most of the pathogens are enteric forms[1]. The actual pathogen content of any given sewage sludge would reflect the enteric infections actually occurring in the particular community, and would tend to vary from place to place.

   Four groups of pathogens are normally to be found in sewage sludges:

   a) Viruses - The most important viruses found in sewage and therefore sludge in North America, are listed in Table 1. Most viruses are species specific, and those infecting animals will not infect man; however, exceptions may exist in the case of some types of rota and

reoviruses. The process of sludge digestion, whether aerobic or anaerobic reduces the numbers of these viruses but does not result in complete elimination[2,3].

b) Bacteria - Table 2 lists the bacterial pathogens of major concern in sewage sludges. A large number of pathogens secreted and excreted from humans may be present, but the enteric forms such as Salmonellae are probably more important with respect to the use of sludge and/or compost. Some species of Salmonellae can infect both man and animals, with the latter serving as a reservoir of infection, and the use of the sewage sludge or sludge products in agriculture serving to recycle the organisms in the environment. Again, the process of sludge digestion is not entirely successful in eliminating all of these microorganisms[4,5] although the numbers would be expected to be greatly reduced. High numbers of Gram negative bacteria, including Klebsiella pneumoniae and Pseudomonas aeruginosa are found in raw or digested sewage sludge[6].

c) Protozoa and Helminths. Parasitic protozoa and helminths constitute a large group and are shown in Table 3; the cysts and ova of these parasites because of their weight tend to settle out of sewage and concentrate in the sludge[7]. Giardia lamblia is recognized as the most common protozoan parasitic disease, and of the helminths Ascaris lumbricoides (common roundworm), Trichuris trichiura (human whipworm), Necatur americanus (hookworm) and Taenia saginata (human tapeworm) are the most frequently encountered[8]. The human tapeworm is transmitted to man upon consumption of undercooked beef from cattle which have ingested the eggs from pasture contaminated by human sewage. Giardia lamblia, ascaris and trichuris infections are acquired by direct ingestion of viable cysts and ova, whereas hatched larvae from the hookworm ova infect man by penetration

through the skin.

From the tables, it can be seen that the sludge can contain organisms which are harboured by both man and animals and some organisms originating in animals are capable of causing disease in humans. Domestic animals may provide a reservoir of infection for some of the human bacterial viral and parasitic infections. An important source of the pathogens from animals in sewage and sludge is the waste from abattoirs and meat and poultry processing plants[9]; animal feces containing pathogenic organisms are also washed into sewers by stormwaters[10]. Salmonellae organisms may be excreted by at least 1% of the population at any given time[11], and from 1.5 to 20% of the population can be shown to have Giardia lamblia cysts in their feces[12].

2. Bulking Materials

a) Wood chips and/or Sawdust and Plant Wastes. Certain microorganisms associated with wood and plant wastes are capable of causing disease in man. They are probably more appropriately termed 'secondary pathogens', so-called because they usually attack only hosts in a weakened physiological state. The organisms or groups of organisms which can be associated with wood and plant wastes are shown in Table 4. These organisms are most likely to produce their effects upon inhalation, and previous conditions in the host (such as the presence of bronchitis, asthma, defective host defenses etc.) tend to predispose individuals to infection[13].

Plant wastes may contain human enteric pathogens due to contamination with human or animal excreta eg. from the use of sewage or sludge as soil conditioners.

b) Municipal Garbage. The number and variety of pathogens found in municipal garbage will vary with the source and composition of the garbage. Because of increased use and disposal of disposable diapers,

municipal waste can be a source of human enteric viruses[14] and bacteria. Garbage also contains large quantities of pet feces (predominantly dog and cat) disposed of in household waste; these feces may also be a potential source of organisms pathogenic to humans (see Tables 1, 2 & 3). The concentration of pathogenic organisms per unit weight of garbage would be less than that in sewage sludge, but nonetheless pathogens are contributed from this source.

Composting Process

a) Microbial Activity - Composting is a microbiological process which partially stabilizes organic materials. The composting materials become heated due to the activity of oxidative, thermophilic (heat loving) microorganisms[15], comprising members of the Actinomycete group and various fungi and bacteria. At the beginning of the composting process, all bacterial groups multiply; as the temperature increases, the mesophilic groups (including the nitrogen-fixing bacteria) decrease in number resulting in a loss of nitrogen as ammonia. When the rapid breakdown of nutrients (the active stage) is more or less complete the temperature begins to decrease; during this cooling, the nitrogen-fixing bacteria again increase and the final breakdown of material and nitrate production is completed during the stabilization period. The eventual onset of nitrification indicates that treatment has neared completion[16].

For optimal microbiological activity, the correct balance of nutrients must be available. The most important nutrients are carbon and nitrogen and about thirty units of carbon are required by living organisms for every one unit of nitrogen[17]. The bacteria use two thirds of the carbon supply for energy production and one third is combined with the nitrogen to produce cell protoplasm; as cells die the released nitrogen is used by other organisms. Thus the nitrogen is recycled whilst the carbon content continues to be reduced. If the carbon/nitrogen ratio exceeds

thirty to one, the depletion of nitrogen results in slower microbial growth, a lower heat output and consequently less efficient pathogen destruction; a lower ratio results in rapid composting but a loss of nitrogen (as ammonia) and potentially soil conditioning value from the final product[18]; nitrogen loss in composting should normally be less than 10%. Certain abiotic factors (chemical or physical) can affect the composting process efficiency. Thus, excess wetness or compaction can result in poor ventilation, lack of oxygen and decreased microbial activity; similarly, insufficient moisture can be detrimental. However, correction of the deficiency normally results in prompt recovery of the process[16].

In composting, the key metabolic waste is heat[16] and the aim in process control is to maintain a sufficiently high temperature to ensure pathogen inactivation, whilst maintaining a favourable temperature for the moderate thermophiles active in degradation[19].

b) Pathogen Inactivation. Organisms pathogenic to humans and animals from a variety of sources are present in raw compost. If the composting process is not carried out properly, viable parasites and other pathogens may be disseminated, and present a hazard to man or animals exposed to the product or the crops fertilized with it[20]. There are a number of different kinds of composting systems; the process can be carried out either in enclosed mechanical systems or in open piles or windrows, with or without forced aeration. Each kind of system is designed to promote optimum aeration and the development of high temperatures. However, to be effective in the destruction of pathogens, the system must ensure that all of the material is exposed to the high temperatures for a sufficiently long period of time. Bacteria, particularly Salmonellae species, which survive initial exposure to high temperatures and are transferred to a cooler portion of the composting mass upon

mixing, may multiply[21]; high numbers are then redistributed through the material upon further mixing.

Design controls on the composting process must therefore ensure:

a) the development of sufficiently high temperatures to achieve pathogen destruction,

b) exposure of all composted material to the high temperature for a sufficient time,

c) the prevention of the development of conditions favourable to pathogen regrowth,

d) protection to the workers at the composting plant, from pathogenic microorganisms.

Most workers agree that temperatures between 60° and 70°C maintained for 3 days would result in the complete destruction of pathogens[22, 23]. At a temperature of 55°-60°C a 7 day exposure period has been recommended[24], although other time/temperature envelopes have been proposed[18]. Ascaris eggs (regarded as among the most resistant infective agents to be found in compost) have been reported as being destroyed after sixty minutes at 60°C, and Salmonellae species after 30 minutes, with viruses destroyed even more rapidly[25]; the studies were carried out in a fully aerobic, enclosed completely mechanized plant. The extended time allowed in the composting process is to allow for the expected non-uniformity of conditions within the composting mass. If lethal temperatures could be assumed to prevail throughout the reactor, then the exposure time required for pathogen kill would become a matter of hours rather than days[26]. To maintain the material at the lethal temperatures, static windrows or piles may be "capped" with a layer of stabilized material for insulation purposes. In turned windrows, mixing must be done sufficiently to ensure all the material is exposed to the lethal temperatures and to prevent recontamination becoming a factor, turning at least 5 times in a 5-7 day period

is recommended[27].

Other commercial fertilizers and soil amendments have been shown to contain human pathogens. Thus, bone meal (including heat treated varieties) and fish and blood meals can contain Salmonellae species[28]. Aspergillus fumigatus levels in soil amendments were found to be comparable to those in compost[15]. Compost produced under adequate process controls, should not result in hazard to the user provided normal habits of personal hygiene are employed.

Risks to the workers at the composting plant can be reduced by managing the plant processes, using appropriate techniques and taking precautionary measures. Since all materials used in the composting process may contain potential pathogens, handling precautions should apply to both sludge and bulking material. The transmission of pathogens may take place in two ways:

a) hand contact with infectious materials followed by transfer to the mouth or eyes. This may be avoided by the practice of normal personal hygiene and the provision of protective clothing such as overalls and gloves.

b) inhalation of dust and particulate material generated by the process or during the handling of sludge and/or bulking materials. Thermophilic organisms, causing the allergic type reactions such as Streptomyces species and Aspergillus fumigatus reactions may increase in numbers during the composting process. The growth of the latter, at least, can be reduced by the use of non-cellulosic bulking agents, rather than wood chips or sawdust[15], and/or increasing the moisture content of the compost[29], since Aspergillus fumigatus multiplies excessively in compost slightly too dry for optimal bacterial growth.

Precautions afforded the workers should include minimizing the exposure to dust by periodic water spraying and provision of, as a minimum,

dust masks, or preferably respirators. Compost facility designs should not be such as to enclose workers in a part of the operation where dust would be generated. Workers with existing medical conditions, which would predispose them to possible infection by airborne organisms should be screened in the employment process, and all workers should be given periodic medical check ups. It would also appear prudent to avoid locating composting facilities near hospitals or other health care facilities, which contain a population of already compromised individuals.

Conclusions

Compost produced from sewage sludge and various bulking material should be sufficiently free of pathogenic microorganisms, provided adequate process controls are applied. Some precautions should be applied for the protection of plant workers from possible infection, and in the location of composting sites.

1. C.G. Golueke. Biocycle 24, 52, 1983.
2. A. Eisenhardt, E. Lund & B. Nissen. Water Res, 11, 579, 1977.
3. P.W. Kabler. Sewage & Ind. Wastes 31, 1373, 1959.
4. R.E. McKinney et al. Sewage & Ind. Wastes, 30, 1467, 1958.
5. H. Heukelekian & M. Albanese. Sewage & Ind. Wastes, 28, 1094, 1956.
6. D.J. Dudley et al. App. & Environ. Microb. 39, 118, 1980.
7. B.D. Hays. Water Research, 11, 583, 1977.
8. D.C. Watson et al. Water Pollut. Control. 82, 285, 1983.
9. J.A. Hudson & H. Fennel. Wat. Pollut. Control 79, 370, 1980.
10. A.A. Qureshi, COA Report #87, MSS Canada, 1978, #En 43-11/87, ISBN 0-662-10190-1.
11. Ministry of Agriculture and PHLS. J. Hyg. (Camb.) 63, 223, 1965.
12. L.E. Witherell and L.M. Herbert. J. NEWWA 91, 102, 1977.
13. Allen, J.C. Infection and the Compromised Host. Williams & Wilkins Co., Baltimore, 1976.
14. M.D. Sobsey. Am. J. Pub. Hlth. 68, 858. 1978.
15. W.D. Burge & P.D. Millner. Sludge - Health Risks of Land Application ed. Bulton, Damrod, Edds & Davidson. Ann Arbor Science Publishers Inc. 1980.
16. M.S. Finstein et al. JWPCF 52, 2675, 1980.
17. P.L. Bishop & C. Godfrey. Biocycle, 24, 1983.
18. E. Epstein. Workshop on the Health and Legal Implications of Sewage Sludge Composting Energy Resources Company Inc., Cambridge, M.A. 1979.
19. M.S. Finstein et al. Sludge Composting - Utilization. Rational Approach to Process Control. Final Report to USEPA-NJDEP-CCMUA 1980.
20. R.G. Arther et al. JWPCF 53, 1334. 1981.
21. C.F. Russ & W.A. Yanko. App. Environ. Microbiol 41, 597, 1981.
22. J.S. Wiley & S.C. Westerberg. App. Environ. Microbiol. 18, 994, 1969.

23. M.T. Morgan & F.W. MacDonald. J. Environ. Health 32, 101, 1969.

24. S.A. Ware. EPA-600/8-80-034. Municipal Environmental Research Laboratory, Office of Research and Development, U.S. EPA Cincinnati, Ohio, 45268, Aug. 1980.

25. K. Kawata. Water and Sewage Wks. 124, 76, 1977.

26. C.G. Golueke, Biocycle. 23, 28, 1982.

27. Technical Bulletin. Composting Processes to Stabilize and Disinfect Municipal Sewage Sludges. EPA 430/9-81-011, US EPA Office of Water Program Operations, Washington, D.C. 20460, 1981.

28. H. Williams Smith et al. J. Hyg. (Camb.) 89, 125. 1982.

29. Millner, P.D. et. al. App. Environ. Microbiol. 34, 765, 1977.

30. R. Selden et al. Ann Internal. Med. 74, 657, 1971.

31. W.M. Oliver. Composting - Theory and Practice for City Industry and Farm. The J.G. Press Inc., Emmaus Penn., P.63, 1981.

32. C.S. Clark et al. Sludge - Health Risks of Land Application. Ann Arbor Science Publisher Inc. The Butterworth Group. Ann Arbor, Mich. p.215, 1980.

33. M. Lundholm and R. Rylander. J. Occup. Med. 22, 256, 1980.

34. S.T. Bagley et al. App. Environ. Microbiol. 36, 178, 1978.

TABLE 1*. VIRUSES FOUND IN SEWAGE AND SEWAGE SLUDGE

Virus	Disease	Source/Reservoir
Hepatitis A	Infectious hepatitis	Man, primates
Coxsackieviruses A&B, Echovirus	Aseptic meningitis, rash	Man, possibly animals
Adenovirus, Reoviruses	Respiratory disease	Man and animals
Poliovirus	Poliomyelitis	Man
Rotavirus		Man, domestic animals
Parvovirus	Gastroenteritis	Man
Reovirus		Man, animals

*based on a Table in "Health Hazards Associated with Wastewater Effluents and Sludges" in Proc. of Conf. on Risk Assessment and Health Effects of Land Application of Municipal Wastewater and Sludge. University of Texas at San Antonio. 1977.

TABLE 2*. BACTERIAL PATHOGENS FOUND IN SEWAGE AND SEWAGE SLUDGE

Bacteria	Disease	Source/Reservoir
Salmonellae (~1700 types)	Typhoid fever, salmonellosis	Man, domestic and wild animals and birds
Shigellae (4 species)	Shigellosis, bacillary dysentery	Man
Escherichia coli (enteropathogenic types)	Gastroenteritis	Man, domestic animals
Mycobacterium tuberculosis	Tuberculosis	Man**

*based on a Table in "Health Hazards Associated with Wastewater Effluents and Sludges" in Proc. of Conf. on Risk Assessment and Health Effects of Land Application of Municipal Wastewater and Sludge, University of Texas at San Antonio, 1977.

**E.G. Carrington, Water Research Centre, Stevenage Laboratory, Hertfordshire, England, 1977.

TABLE 3*. PROTOZOA AND HELMINTHS FOUND IN SEWAGE AND SEWAGE SLUDGE.

Organism	Disease	Source/Reservoir
a) PROTOZOA		
Entamoeba histolytica	Amoebiasis	Man
Giardia lamblia	Giardiasis	Man, domestic and wild animals
(Balantidium coli)	(Balantidiasis)	Man, swine
b) HELMINTHS		
1. Cestodes (Tapeworms)		
Taenia saginata (beef)	Taeniasis	Man
Taenia solium (pork)		Man
Hymenolepis nana	Taeniasis	Man, rat
2. Nematodes (Roundworms)		
Ascaris lumbricoides	Ascariasis (roundworm)	Man, swine?
Necatur americanus	Necatoriasis (hookworm)	Man
Enterobius vermicularis	Enterobiasis (pinworm)	Man
Strongyloides stercoralis	Strongyloidiasis (threadworm)	Man, dog
Trichuris trichiura	Trichuriasis (whipworm)	Man
Toxacara cati)	Visceral larva migrans	Carnivores (cats
Toxacara canis)		and dogs

*based on Tables in "Health Hazards Associated with Wastewater Effluents and Sludges" in Proc. of the Conf. on Risk Assessment and Health Effects of Land Application of Municipal Wastewater and Sludge. University of Texas at San Antonio, 1977.

TABLE 4. MICROORGANISMS ASSOCIATED WITH WOOD OR PLANT WASTES, POTENTIALLY CAPABLE OF CAUSING HEALTH EFFECTS IN HUMANS.

Organism	Disease
Klebsiella pneumoniae[6]	Pneumonia, nosocomial disease[1]
Aspergillus fumigatus	Aspergillosis, allergy[2]
Streptomyces species	Hypersensitivity[3]
Fungi	Hypersensitivity[4]
Gram negative bacterial species	Endotoxic reaction[5]

1 - ref. 30; 2 - ref. 31; 3 - ref. 1; 4 - ref. 1; 5 - ref. 32, 33; 6 - ref. 34.

GUIDELINES FOR AND APPROVALS ASPECTS OF COMPOSTING OPERATIONS

By Frank J. Iliffe[1]

INTRODUCTION

Today I am going to talk about getting composting sites approved. Topics such as this rarely bring audiences to their feet, except perhaps to take an early coffee break.

The 4 R's, as you heard in an earlier paper, are fundamental to Waste Management. These, I will remind you, are:

REDUCTION, REUSE, RECYCLING AND RECOVERY.

However, if you have been involved in approvals processes you may define them differently. Many people are beginning to regard the 4 R's as:

RESENTMENT, RESISTANCE, REACTION, REJECTION.

These days, before you can say Waste Disposal, at least three groups opposing your proposal have been formed.

Why is the public hostile to waste management proposals?

- Because they usually remember only past waste mismanagement, like Love Canal;
- Because they need to blame somebody for the past and today's managers are convenient scapegoats;
- Because they think that the terms 'Wastes' and 'Hazards' are interchangeable;
- Because they fear drops in real estate values; and
- Because we have yet to convince the public that we do things differently nowadays.

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we must take every opportunity, all of us, Governments, Municipalities and everyone involved in waste handling, to convince the public that today's techniques are safe, that through monitoring, we can anticipate and prevent health hazards. If we fail to do so, new solutions to old problems will be delayed, and those old problems may well become bigger.

Through its 'Blueprint for Waste Management in Ontario', the province is making strenuous efforts to inform and involve the public in legislation and regulation reform. However, human nature being what it is , the public, informed or misinformed, usually takes an interest only when there is a nearby waste handling proposal; it is not then going to be reasonable and will demand 100% assurances that no one can give.

No-one ever asks for assurances that new highways will be completely safe. People are delighted with assurances that the number of accidents will be reduced. Why, then, is the public not delighted with our assurances that new sites will be much, much safer?

No matter where we go, waste sites are always opposed. Public concern and apprehension have become a way of life. As a result, disposal sites have become more costly. This is partly because the experts' time at a hearing is very expensive, but it is mainly because the least opposed sites are often the most expensive ones to develop. Composting site proposals are unlikely to be immune to organized public opposition. We would assure the public that MOE will not comprorise on public and environmental safety. Therefore, compost site proponents must ensure that:

- Sites are environmentally sound;
- Development costs will be reasonable;
- Farm land will not be used when other less valuable land will suffice.
- Public concerns can be resolved, at least to the satisfaction of appropriate experts.

Through its legislation, MOE deals with environmental concerns. The legislation and its provisions for hearings and evaluation of alternatives together provide a framework for handling both environmental impacts and other types of impact.

Municipalities increasingly recognise that, for wastes produced within their jurisdiction, a means of disposal must be available and that they are responsible for impacts within and around their boundaries. Therefore, proponents of composting must inform local people and help them to provide input during the planning stage. Such early input can help to minimize the likelihood that near-final proposals, developed at high cost, will subsequently be abandoned. Public involvement should continue after construction, when the site is operating. If the public feels that it will always be able to discuss operating problems with you directly, a polarization of public opposition is less likely to occur.

ONTARIO LEGISLATION

Environmental assessment and public hearings provide a framework for MOE, Municipalities, the proponent and the public to exchange information. We must all use that opportunity effectively. Compliance with environmental legislation is not really costly, although it may appear so. Many of the requirements are plain common sense and are things we should do anyway. In fact, when used wisely and properly, public consultation can reduce costs. It is, after all, sound practice to investigate alternate construction and disposal methods for several different locations, and their impacts. If impacts are assessed only after land has been acquired and designs are complete, it will be too late if we then discover that the site is unsuitable or development will be very costly.

Composting site applications are usually handled under the Environmental Protection Act. In addition, Waste Management System Certificates are required for the transportation of waste materials to composting and other disposal sites.

A Certificate of Approval (Air) under EPA Section 8 may also be required. If there are to be liquid discharges, Ontario Water Resources Act approvals may be required. Multiple hearings, required by several acts, can often be replaced with a single hearing under the Consolidated Hearings Act.

Environmental Assessment Act

Provincial or Municipal composting proposals are subject to the Environmental Assessment Act unless exempted. See Regulation 293. If there is no element of municipal or provincial proponency, or if their cost (in 1977 dollars) is to be less than $2 million, they are exempt.

Proposals can be brought into compliance in three ways:

- By individual environmental assessment. Approvals are given on a case-by-case basis.
- Through exemption by Order or Regulation. For example, if sewage sludge is composted at the sewage treatment plant, the composting operation is exempt from the EAA approval process.
- Through compliance with an approved Class Environmental Assessment.[1,2]. Class EA procedures presently apply to composting proposed for sewage sludge at:
    - The same sewage treatment plant, when the plant is to be expanded or upgraded
    - A different sewage treatment plant
    - A landfilling site.

However, the Act provides that a facility which is subject to the Class EA can be "bumped-up"; an individual environmental assessment would then be required.

The requirements of the Environmental Assessment Act are more complex than those of the Environmental Protection Act, so our Environmental Approvals and Project Engineering Branch should be consulted, to obtain complete information and to determine approvals requirements.

Environmental Protection Act

Under the Environmental Protection Act and Ontario Regulation 309 most wastes may be processed or disposed of only at certified waste disposal sites. Therefore, sites at which wastes are processed into compost require a Certificate of approval. However, agricultural wastes which are disposed of at the same farm are exempt. Composting of a home-owner's wastes on his own lot are similarly exempt.

There are no direct controls on the use of composted material; waste, after composting, is not considered to be "waste". Therefore compost utilization sites, i.e. locations where compost is used are not directly controlled by Ontario Legislation. However, under EPA Sections 38 (2) (c) and (e), MOE can impose conditions, to prevent nuisances or health and safety hazards.

APPROVAL PROCEDURES

Applicants should complete an MOE Form 1645/80, "Application for Certificate of Approval for Waste Disposal Site (processing)", and include comments from the local Medical Officer of Health and the Ministry of Labour, to ensure that the health and welfare of site staff and the public are adequately protected. Certificates issued are normally "Provisional" (Form MOE 140810/79).

Our "Draft Interim Guidelines for Compost Production, Quality and End Use"[5], are available for inspection at MOE Regional Offices. I shall briefly discuss these Guidelines later on.

For most composting proposals there will usually be a "Discretionary" Hearing. After the Hearing, the Regional Director can either issue or refuse a Certificate of Approval. If there is no Hearing, he may issue a Certificate when the application is complete and acceptable. When Hearings are held under EAA, the Environmental Assessment Board, rather than MOE's Director, is the decision-maker.

Composting Sites located on sewage treatment plant properties should accord with our January, 1978 "Guidelines for Land Use Surrounding Small and Medium Sized Sewage Treatment Plants",[3] which relate to odour emissions. Those located on landfilling sites should comply with our "Guidelines for the Establishment, Operation, Management, Maintenance and Closure of Landfilling Sites in Ontario".[4]

Criteria for other composting sites are presented in "Guidelines for Land Use Surrounding Waste Disposal Sites (Composting)"[6]. The actual processing area is normally separated from other land uses by buffer zones at least 100 metres wide, but applicants can obtain advice from our Regional staff. When there is no adjoining residential land use, buffer zone distances can sometimes be relaxed. Buffers should normally be within the site boundaries.

Supporting Information

Additional information should include:

- A map showing site location and zoning, zoning of adjacent properties, the nearest home, the proximity of residential areas, the nearest well, the nearest occupied industrial or commercial building and the nearest watercourse;

- Documentation of the owner's concurrence;
- Documentation of consultation with municipalities and, when municipal wastes are to be used, documentation of municipal agreement;
- Documentation (letter of intent) of the compost end use;
- Sources, types and quantities of materials. Sludges are normally dewatered to a moisture content appropriate to the process. For windrow composting, sludge stabilization may be required to control odours;
- Number, type and size of trucks importing materials, trip frequencies, and routes;
- The total area of the site;
- The depth of water table;
- Surface and sub-surface on-site and off-site drainage;
- The compost storage area; and
- Employee sanitary arrangements.

In addition certain process information is required:

- descriptions of process facilities, equipment, conditions and controls including materials handling facilities and equipment, construction materials, mixing area (if required) modifications to surface and sub-surface drainage patterns and methods of recovery of bulking and stabilizing agents (if used);
- the length of the compost stabilization period and monitoring arrangement proposed;
- details of the air injection and exhaust control systems, and/or the frequency and method of turning or mixing;
- methods of disposal of residues;
- collection, treatment and disposal of runoff waters - approvals under OWRA Section 24 may be required; and
- Contingency plans for the alternate disposal of both raw materials and products.

MUNICIPAL BYLAWS

Municipal by-laws vary from municipality to municipality. Proponents should make careful enquiries to find out what bylaws' impacts on composting proposals will be.

Municipalities can enact by-laws more restrictive than either Federal or Provincial bylaws. However, bylaws which directly or indirectly prohibit the establishment of waste disposal sites can be overturned. Through municipal EPA Section 35 (1), the Minister can, if he wishes direct an Environmental Assessment Board to hold hearings to see if the bylaw should apply to the proponent's proposal. After receiving the Board's report the Minister may determine if the by-law applies to the proposal.

RELATIONSHIP BETWEEN PROVINCIAL AND FEDERAL LEGISLATION

Compost manufacturers should be familiar with both Federal and Provincial requirements. Normally, compliance with both is required. Provincial and Federal legislation occasionally deal with the same subject and may overlap. On rare occasions they may appear to be in conflict. About three years ago, the Federal Government's minimum permissible concentrations for metals in fertilizers exceeded the Provincially recommended maxima for dried and composted sewage sludge. The Federal standards have since been revised.

If there seems to be a problem, ask Federal and Provincial officials to advise you.

FEDERAL LEGISLATION

The Federal Fertilizers Act[7] and the Ontario Guidelines are based on the same principle. That is to say, when either raw or waste materials are applied to land, the potential hazards of metals and other contaminants are balanced against the benefits provided by the nitrogen, phosphorus, potassium and other nutrients and soil conditioners.

Materials Controlled

This Act, and the Federal "Regulations respecting the Regulation and Control of Agricultural Fertilizers"[7] apply to composted materials sold and intended for use:

- as fertilizers;
- as fertilizer supplements; or
- to improve the physical condition of soils.

They can include:

- Dried processed sewage sludge and other sewage by-products;

- Composted manure;
- Municipal waste tankage and industrial sewage;
- Animal tissue and body wastes; and
- Other similar materials.

Materials controlled under federal legislation must be registered prior to use and approved. Labels or shipping notes must specify the amount of each constituent.

Materials Exempt

Some materials which may be exempt include:

- Fertilizers, etc. intended for export;
- Materials which may require treatment prior to sale, e.g. rock phosphate;
- Supplements intended for manufacturing purposes; and
- Fertilizers, etc. imported directly by the user.

However, even exempted materials must not contain injurious or poisonous substances.

FEDERAL AND PROVINCIAL CONTROLS ON METALS

Table I illustrates federal and provincial restrictions on metal concentrations in fertilizers and/or composts. Those restrictions are based on:

- For Ontario - The Draft Interim Guidelines for Compost Production, Quality and End Use - Draft #6 - April, 1982.[5] (In the up-coming edition of the "Guidelines for Sewage Sludge Utilization on Agriculture Land"[8] requirements for composted materials will be deleted).

- For Canada - Agriculture Canada Trade Publication T-4-93[9] (April 2, 1981)

The only Federal restriction which is more onerous than Ontario's is the recommended maximum cumulative selenium addition to soil.

Although Ontario has criteria for chromium and copper, the Federal Government does not.

The Federal cumulative metal additions are permitted over 45 years. Those permitted by Ontario vary according to the metal as follows:

55 years - Cobalt, Copper
50 years - Arsenic, Lead, Zinc
45 years - Chromium, Mercu · Nickel, Selenium
30 years - Cadmium
25 years - Selenium

Thus it is difficult to make a true comparison. If you are interested in adding metals on an annual basis, you will have to do a little arithmetic, to compare average annual additions over the designated periods. I imagine we or our colleagues in the Ontario Ministry of Agriculture and Food will be contacting Agriculture Canada, to see if an agreement on common standards can be reached. In the meantime, Ontario compost producers will want to ensure they meet the toughest standard for each metal.

ONTARIO GUIDELINES FOR "COMPOST PRODUCTION, QUALITY AND END USE"

Draft Guidelines are being developed, on an interim basis, for internal MOE use. MOE Regional staff are prepared to discuss their underlying principles with proponents. This will help us to "field-test" the draft, to ensure that the final draft will safeguard the environment without hampering compost production. I am going to present some of the ideas the draft guidelines contain. We will be very pleased to receive your comments on these ideas.

The Guidelines would apply to all compost manufacture and use in Ontario, except when the wastes used are from agricultural operations or when the producer is going to use the compost himself.

The Guidelines would define compost as "material containing at least 30% organic material which has been produced by aerobic decomposition." Ontario Regulation 309,10 (Section 1.5), defines composting as "The treatment of waste by aerobic decomposition of organic matter by bacterial action, for the production of stabilized humus". It also classifies composting sites and defines them as sites where materials are composted.

The Guidelines' purpose would be to ensure that compost can be produced and used without adversely affecting human and animal health, food production and the natural environment. In addition, they would enable MOE staff to make a rational assessment of systems for production, handling and utilization of compost.

Before we finalize our Guidelines, we will be asking municipal and industrial compost producers to provide us with their comments. In addition, we will be scrutinizing recently published literature on compost research and practices. For

example, the United States Department of Agriculture Information Bulletin Number 464 "Utilization of Sewage Sludge Compost as a Soil Conditioner and Fertilizer for Plant Growth"[11] contains much information which will be of interest to Ontario researchers and compost producers. The Association of American Plant Food Control Officials, which should be consulted before compost is marketed in the US, has sponsored a 'Uniform State Fertilizer Bill[12]' which has been adopted in several jurisdictions.

Monitoring Compost Operations

In order to ensure that pathogens have been inactivated, the operator will be obliged to monitor several process control parameters such as:

- Quality of incoming raw materials;
- Aeration or Oxygenation;
- Drainage;
- Injection of activators, retarders and stabilizers; (when used)
- Climate (or adjustments therefor);
- pH;
- Nitrogen retention;
- Carbon to nitrogen ratio;
- Temperature;
- Moisture content; and
- Materials handling.

However, MOE's main objective is to ensure that compost does not have harmful or deleterious effects. We regard exposure to high temperatures is the key to pathogen inactivation. Therefore, temperature monitoring is the only mandatory process monitoring we currently propose.

Temperature Monitoring

More uses might be permitted when the type of temperature monitoring used provides a high degree of assurance that critical temperatures are achieved for a sufficiently long period of time if such a presumption cannot be made, the materials would have to be disposed of at another certified disposal site or reprocessed.

If material by-passes the high-temperature zone, it will not be pathogen free. Processes and the storage of processed materials should prevent bypassing and recontamination. As an additional precaution waiting periods, between compost application in agriculture and in public access areas, may be required.

In processes such as the Beltsville Static Pile process, temperature readings are obtained by means of uniformly

spaced probes. The depths of the probes are adjusted so that, as the compost volume reduces, the sensitive ends of the probes are in within the range of 30 to 45 cm from an exterior face. At least 4 probes per pile or windrow are used. The actual number would depend on the size of the batch or, in continuous processes, on the capacity of the equipment. Continuous feedback, from continuous-recording temperature probes, controlling aeration and/or moisture, would give good assurances of compost quality. However, the probes' adequacy would still have to be verified by tests with additional movable probes. The tests would be conducted immediately after plant commissioning and at least twice a year thereafter. The number of probes would be based on those available in similar proven installations. When the probes are read visually, readings should be taken twice a day and recorded, to demonstrate that critical temperatures are being reached. With such monitoring, assurance of pathogen inactivation would be not be as great as when processes are controlled by feedback.

Compost Application Rates

Maximum permitted compost application rates would be determined according to the provisions of Table 1. In addition, phosphorus applications should not cause soil phosphorus concentrations to exceed 60ug/g. The maximum permissible phosphorus addition would be 1200 kg (e.g. 2750 kg of phosphorus pentoxide) per hectare over 25 years. Such an addition would elevate soil phosphorus from 8 to 60 ug/g.

Permissible Uses

The circumstances in which compost can be used might be dependent on the reliability of the temperature monitoring and the controls available to restrict metal application and protect consumer health. Typical uses would be:

- Agriculture - application rates should be carefully controlled.
  - Fields for grazing and — Depending upon the extent of guarantees on pathogen inactivation, waiting periods between spreading and grazing in accordance with the sludge utilization guidelines,
- Landfill sites - as an additive to final cover;
- Sand and gravel pit reinstatement "
- Mine tailings sites "
- Highway bank stabilization - as an additive to top soil dressing
- Airports

The application of compost on home gardens is a particularly contentious issue, because application rates cannot be controlled vis-a-vis metal build-up in soils and because of the risks, albeit very small, of incomplete pathogen inactivation.

In conclusion, I would re-iterate that the Waste Management Branch would appreciate your comments on these guideline proposals.

REFERENCES

1. Class Environmental Assessment Document for the Expansion or Upgrading of an Existing Sewage or Water System. This document relates to MOE projects. Ministry of the Environment, Environmental Approvals and Project Engineering Branch.

2. Class Environmental Assessment for Municipal Sewage and Water Projects. Municipal Engineers Association - August 1982.

3. Guidelines for Land Use Surrounding Small and Medium-sized Sewage Treatment Plants, Ministry of the Environment, - July 1978.

4. Guidelines for the Establishment, Operation, Management, Maintenance and Closure of Landfilling Sites in Ontario, Ministry of the Environment, Waste Management Branch - 1981.

5. Draft Interim Guidelines for Compost Production, Quality and End Use, Ministry of The Environment, Waste Management Branch, Unpublished.

6. Guidelines for Land Use Surrounding Waste Disposal Sites (Composting), Ministry of the Environment, Environmental Approvals and Project Engineering Branch.

7. 'Fertilizers Act' and 'Regulations respecting the Regulation and Control of Agricultural Fertilizers' Agriculture Canada. August 1979.

8. Guidelines for Sewage Sludge Utilization on Agricultural Lands. Ontario Ministry of the Environment, Ontario Ministry of Agriculture and Food and Ontario Ministry of Health. 1981.
(New revision publication expected late 1984)

9. Agriculture and Trade Publication T-4-93. Agriculture Canada - April 2, 1981.

10. Ontario Regulation 309.
Queens Printer for Ontario

11. US Dept. of Agriculture Information Bulletin 464 "Utilization of Sewage Sludge Compost as a Soil Conditioner and Fertilizer for Plant Growth, US Dept. of Agriculture, Agricultural Research Service. (Superintendent of Documents US Govt. Printing Office Washington DC 20402 - August 1984.)

12. Uniform State Fertilizer Bill. Association of American Plant Food Control Officials. 1982.

TABLE I

LIMITING METAL CONCENTRATIONS AND APPLICATIONS UNDER THE FEDERAL FERTILIZER'S ACT AND UNDER THE ONTARIO DRAFT INTERIM COMPOSTING GUIDELINES

METAL	MAX. ACC. METAL[1] CONCENTRATION (mg/kg)		MAX. CUM. METAL ADDITION TO SOIL (kg/ha)	
	Canada[2]	Ontario[3]	Canada[2]	Ontario[3]
Arsenic	75	70	15	14
Cadmium	20	10	4	1.6
Cobalt	150	150	30	30
Chromium	-	1000	-	210
Copper	-	750	-	150
Mercury	5	4	1	0.8
Molybdenum	20	20	4	4
Nickel	180	160	36	32
Lead	500	450	100	90
Selenium	14	12	2	2.4[4]
Zinc	1850	1650	370	330

[1]Based on the total application, over 45 years, of materials containing 5% or less nitrogen. For higher nitrogen concentrations, metal concentrations may be proportionately increased.

[2]Excerpted from Agriculture Canada Trade Memorandum T-4-93 (July 2, 1981) (applies to composts which are sold).

[3]Based on Ontario's unpublished Draft Interim Guidelines for Compost Production, Quality and End use. (Draft #6 - April 1982) (Tentatively applies to all composts.)

[4]At present, the only Federal fertilizer restriction which exceeds Ontario compost restrictions is with respect to the maximum recommended cumulative addition of selenium to soil.

ALTERNATIVE COMPOSTING PROCESSES

Andrew J. Higgins*

Introduction

The composting process can be divided into several unit operations as shown in Figure 1. The major components include dewatering of sludge, mixing of dewatered sludge and the bulking agent (i.e. wood chips, shredded bark, saw dust, refuse, etc.), active composting, curing and final screening. All types of composting incorporate these unit processes in their basic design.

System Types

The sewage sludge composting process is divided up into three main classes of systems: windrow, static pile and in-vessel.

. Windrow Systems

The windrow system involves stacking of the mixed compost material in small piles called windrows of approximately 4-6 feet in height and with a base of between 8-10 feet.

This technique of composting is characterized by frequent turning of the windrows by either windrow composting machines or front end loaders. This turning helps to mix the materials, promote aeration and enhance the destruction of pathogens. Thermophilic temperatures (greater than 50°C) are rapidly attained and maintained for approximately 3-4 weeks. During the initial stages of composting, the windrow is usually turned every day. After approximately 5-7 days

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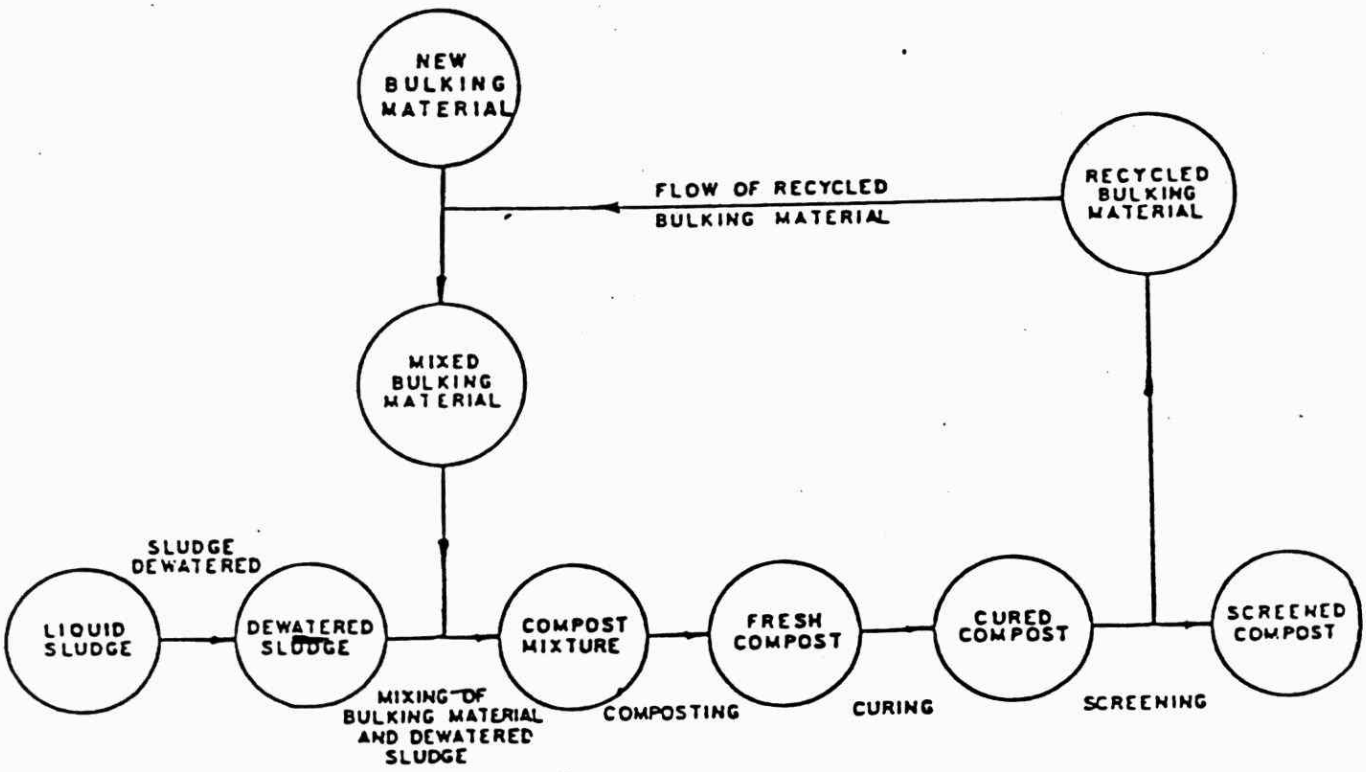


FIGURE - Unit Operations of Composting Process

of active composting, the turning frequency is reduced to only every other day or every third day depending on the temperature. During the last week of composting, the windrow may only be turned once.

After the active period of composting (3-4 weeks), the windrow is broken down and stacked in a pile for curing. This usually lasts between 3-6 weeks before the compost is ready for distribution.

. **Static Pile**

This technique of composting is characterized by large, stationary static piles of material placed on top of perforated pipe. Since the pile is stationary, aerobic conditions are maintained by either pulling air down through the pile or forcing it up. A blanket of finished compost is usually used on the outer surfaces of the pile to ensure uniform temperature distribution, thereby ensuring thermophilic temperatures in all extremities (see Fig. 2).

In the static pile composting system, the dewatered sludge is mixed with a bulking agent, such as wood chips, in the volumetric ratio of 1 volume of sludge to 2 volumes of wood chips. The mixture is placed on piles formed to a height of 6-7 feet with aeration pipes placed in the base of the piles. Forced aeration is achieved with the use of a small blower attached to the piping ventilation system. Composting is conducted in these ventilated piles for approximately 3-4 weeks during which temperatures exceeding $55^{o}C$ are generated.

The active compost piles are broken down after 3-4 weeks and placed into larger unaerated piles for an additional 3-4 weeks. During this cure phase, the composting pile equilibrates to ambient temperatures and is ready for screening. The screening operation

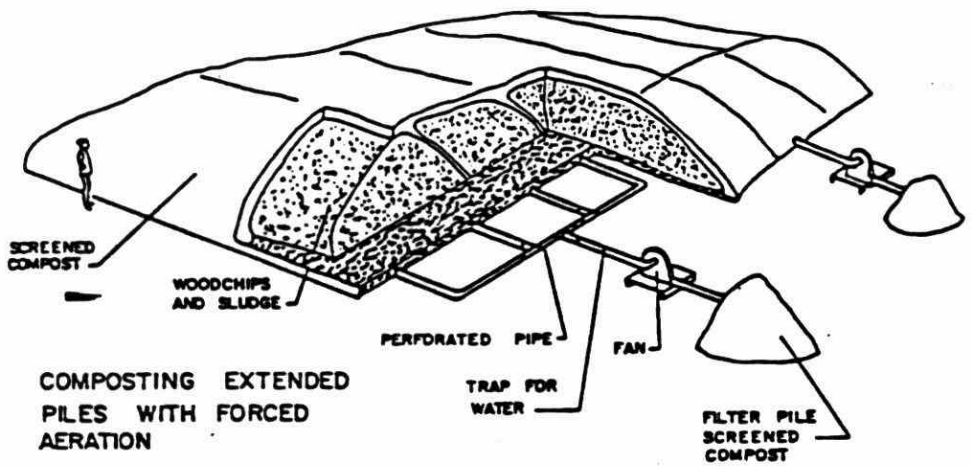


FIGURE - 2 SCHEMATIC DIAGRAM OF EXTENDED AERATED PILE SHOWING CONSTRUCTION OF PILE AND THE ARRANGEMENT OF AERATION PIPE

removes the undecomposed wood chips from the compost and recycles them back into the process. The screened compost is then ready for distribution.

. **In-Vessel**

The term In-Vessel refers to composting systems which take place in enclosed reactors or vessels. The type of facility varies depending on the method of operation. The reactor used in these systems are generally designed to maximize composting efficiency by controlling environmental factors such as airflow temperature.

The number and type of composting systems available is quite large and constantly changing. However, several basic designs are currently being marketed in the U.S. and Canada. The In-Vessel systems can be divided up into four main classes of systems including rotary drum, vertical silo, and horizontal silo systems.

— **Inclined Rotary Drum**

This system of composting uses a rotary drum for both mixing of the sewage sludge and bulking agent (usually municipal solid waste) and active composting of the mixture (i.e. Dano, Eweson). Therefore, this device eliminates the need for a separate mixing device. In addition, the rolling and tumbling action of the drum shreds the mixture, thereby reducing the need for shredding. However, some systems using the inclined rotary drum still use shredding to further reduce the particle size of the mixture.

The sludge in these facilities can be added as either a dewatered or liquid sludge depending on the quantity available and its form. The rotary drum composters normally provide 1-2 days of

residence time for active composting (Dano, Arus Ruthner, Buhler-Miag). However, composters with residence time as high as five days have been built (Eweson Digestor).

After the initial 1-2 days of the active phase, the material is coarse screened to remove non-biodegradable materials and placed in windrows for 1-2 months. The windrows serve as a combination of active composting during the initial stages and curing during the final stages. The windrows can be turned with either a windrowing machine or a front end loader. Covered and open areas have been used for this phase of the process.

. **Vertical Silo Composters**

These composters are designed using a circular or rectangular silo either single staged or partitioned. These vessels are mounted with the long axis in the vertical direction. Sewage sludge and the bulking agent are premixed and placed into the top end of the reactor vessel using bucket elevators or similar materials handling equipment. The mixture moves down through the vessel by gravity and is removed by the use of a large rotating auger at the bottom of the silo. New material is continuously added to offset the removal of finished compost. Examples of such systems include Taulman/Weiss, Purac (ABV), and American Bio Tech (Air Lance).

In most of the vertical silo composters air is injected through the bottom or side walls of the reactor to ensure that aerobic conditions are maintained. Residence time in the reactor is approximately 1-2 weeks after which the material is removed and either windrowed or placed into a cure reactor.

. Horizontal Silo Composters

These composters are horizontal silos or tunnels having a rectangular shape. The vessels are mounted with the long axis in the horizontal directions. An example of this system is the BAV Tunnel Reactor. They are somewhat similar to the vertical reactors in concept but are different in design orientation. The horizontal tunnel can not use gravity for movement of the material through the reactor but instead must use some type of piston actuated pressure plate to push the material through.

The sewage sludge-bulking agent mixture is introduced into the head end of the reactor. The rear portion of the vessel is opened and the piston is actuated. This forces the new material into the reactor and expels the finished compost. Air is introduced along the walls of the vessel. Residence time in the reactor varies from 1-2 weeks plus several weeks for curing.

Another type of horizontal silo is the concrete bunker trough with a mechanical mixing device suspended over the trough mounted on rails for mobility. There are several different mixing devices used in these systems (i.e. Paygro, Siloda, Okada, etc.). They all have the effect of mixing the material and aerating it. They also serve as unloading devices for removing the finished compost from the silo. Air for these systems is supplied through the base of the trough through forced aeration pipes. Composting using this system usually takes between 2-3 weeks for the active stage. After this time, the material is usually cured in windrows outside the reactor vessel.

Comparison of Systems

The advantages and disadvantages of the various composting systems are presented in Table 1. The major advantages of composting over other treatment alternatives include year-round operation, good pathogen control, easy storage of the end product without odor problems, and greater acceptability by the public of the compost product compared to other forms of sludge. On the other hand, there appear to be several potential problems with composting. In the case of windrow and static pile composting, the operational costs are quite high. In addition, these two composting techniques are known to produce slight odors which may be a problem depending on the location of the composting facility. The In-Vessel systems have low operational costs but very high capital costs compared to windrow and static pile composting. In addition, these composting facilities have no odor or dust problems and use very little land.

All of the composting systems discussed produce a compost product which must be disposed of in the market place. It appears from existing facilities in the U.S. and Canada that market development for compost is achievable. Composts produced from animal manure appear more marketable than sewage sludge. Furthermore, composts produced from municipal solid waste are the most difficult to market due to the percentage of nonbiodegradables in the compost.

Conclusion

The use of composting has been widely practiced for the treatment of animal manures, sewage sludge and municipal solid waste. Because of the diminishing number of landfills in the U.S. and Canada and the high cost of other alternatives, composting will continue to play a dominant role in the treatment and utilization of organic residues.

TABLE 1

RELATIVE ADVANTAGES AND DISADVANTAGES OF COMPOSTING

Composting Method	Advantages	Disadvantages
WINDROWING	1. No bulking agent required. 2. No curing required. 3. Operationally simple. 4. Low capital investment. 5. Easy to store final compost product without odor problems.	1. Relatively large land area requirements. 2. Potential odor problems. 3. Difficulty in winter and during heavy precipitation and snow fall. 4. Difficulty in achieving adequate composting temperatures.
STATIC PILE	1. Low energy requirements compared to windrowing. 2. Rapid temperature rise for good efficient thermophilic composting. 3. Better control of odors compared to windrowing. 4. Good stabilization in a relatively short period of time. 5. Easy to store finished compost product for long periods of time without odor problems. 6. Low capital investment. 7. Continuous year-round operation during winter and inclement weather.	1. High operating and maintenance costs. 2. Bulking agent required (i.e. wood chips) which have a high cost and are only 67% recoverable per compost cycle. 3. Some odor and dust problems.
IN-VESSEL	1. Enclosed systems eliminate odors. 2. Small land requirement. 3. Low operational costs compared to the other composting systems. 4. Continuous year-round operation. 5. Easy storage of compost product.	1. High capital costs. 2. Complex design requiring maintenance.

DESIGN CONSIDERATIONS FOR HIGH RATE MECHANICAL COMPOSTING

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DESIGN CONSIDERATIONS FOR HIGH RATE MECHANICAL COMPOSTING SYSTEMS

INTRODUCTION

High rate mechanical composting systems are rapidly growing in popularity in the United States. Many operating agencies are seriously considering such processes as a major component of sewage sludge management programs. The growing acceptance of compost by the market place and the advantages of high rate systems provide a very effective alternative for sludge management.

The purpose of this paper is to present a discussion of high rate mechanical composting systems as they relate to sewage sludge. A description of high rate system components, process variables and process control considerations are also presented. It should be emphasized that high rate mechanical composting systems are still evolving and developing. It is not possible to completely describe all of the aspects of high rate mechanical composting in one paper. It is, however, intended that this document provide a starting point.

HIGH RATE PROCESS DEFINITION

High rate mechanical composting systems represent a logical development of composting technology. The oldest known composting process is the Windrow Process. In this process the objectives of sewage sludge composting (stabilization, pathogen destruction, and moisture reduction) were accomplished in excess of 40 days. The 1970's represented the advent of the aerated static pile which reduced the composting period to 21-30 days. With the introduction of high rate mechanical systems the

composting period was further reduced to 14 days. For the purpose of this paper, therefore, high rate system will be defined as those requiring 14 days or less to complete the composting process.

HIGH RATE COMPOSTING OBJECTIVES

The discussion presented herein is directed at the composting of sewage sludge. Sewage sludge can be classified as a high moisture organic waste. This feedstock poses unique problems for any compost process. The provisions of high rate processes, however, offer the capability to handle these problems.

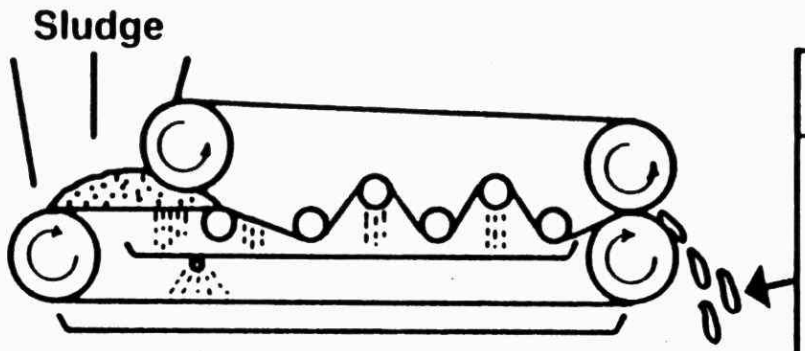
Feedstock Problems

The major problems that are associated with the feedstock sewage sludge are illustrated in Figure 1 and summarized below.

- o Moisture Content. Sewage sludge is typically introduced into the compost process subsequent to dewatering. The moisture content of dewatered sludge (sludge cake) is usually between 70 and 80 percent by weight. High moisture content can limit the compost reaction by reducing operating temperatures. On the other hand, a moisture content which is too low can lead to excessive temperatures which will also limit proper operation.

- o Volatile Solids. A typical mixture of raw primary and waste activated sludge has a volatile solids content of 70 to 90 percent. The goal in composting is to stabilize such a sludge by reducing volatile solids by 50 to 80 percent. A sludge with a high volatile solids content, referred to as "hot sludge", can limit the composting process by producing excessive temperatures

FIG. 1 FEED STOCK CHARACTERISTICS



DEWATERED SLUDGE CAKE

Moisture content = 70 - 80 %
Volatiles content = 75 - 80 %
Pathogen concern
Non-porous material

in the reactor. A sludge with low volatile content will not generate sufficient heat in the reactor to permit the process to function.

- o Non-porous Material. Dewatered sludge is a non-porous material. In addition, it tends to compact further if stored for any period of time thus reducing porosity. This feature of sludge cake can restrict air flow and impede proper distribution in the reactor, thereby limiting aerobic microbial actions, drying, operating temperatures, and pathogen kill.

- o Pathogen Kill. Sludge cake contains pathogens which would be unacceptable in the compost product regardless of intended use. Complete pathogen destruction is essential.

- o Materials Handling. Historically sludge cake has proven difficult to handle and convey, particularly subsequent to storage. While this is an operating problem not unique to high rate processes, it will be briefly addressed.

Process Objectives.

A very basic block diagram of the high rate process is illustrated in Figure 2. As can be observed, the reactor inputs are sludge cake, amendment and controlled air. The output is product compost, exhaust gas, and spent amendment. The spent amendment may or may not have to be separated from the product depending upon the ultimate intended use of the compost.

Having at this point a "black box" called a high rate reactor the question becomes: How is that black box designed and controlled to obtain the compost process objectives in 14 days? The process objectives are as listed in Table 1.

FIG. 2 HIGH RATE REACTOR BLOCK DIAGRAM

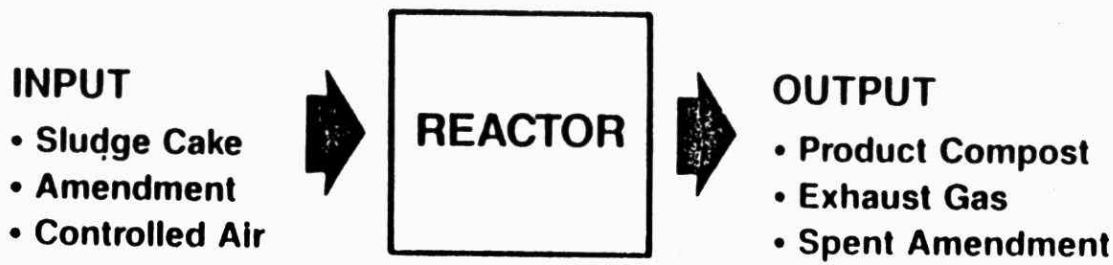


TABLE 1. HIGH RATE PROCESS OBJECTIVES

Item	Description
Stabilization	Volatile Solids Reduction (50-80%)
Moisture Content	Product Moisture (30-40%)
Pathogen Destruction	Complete

HIGH RATE PROCESS PROVISIONS

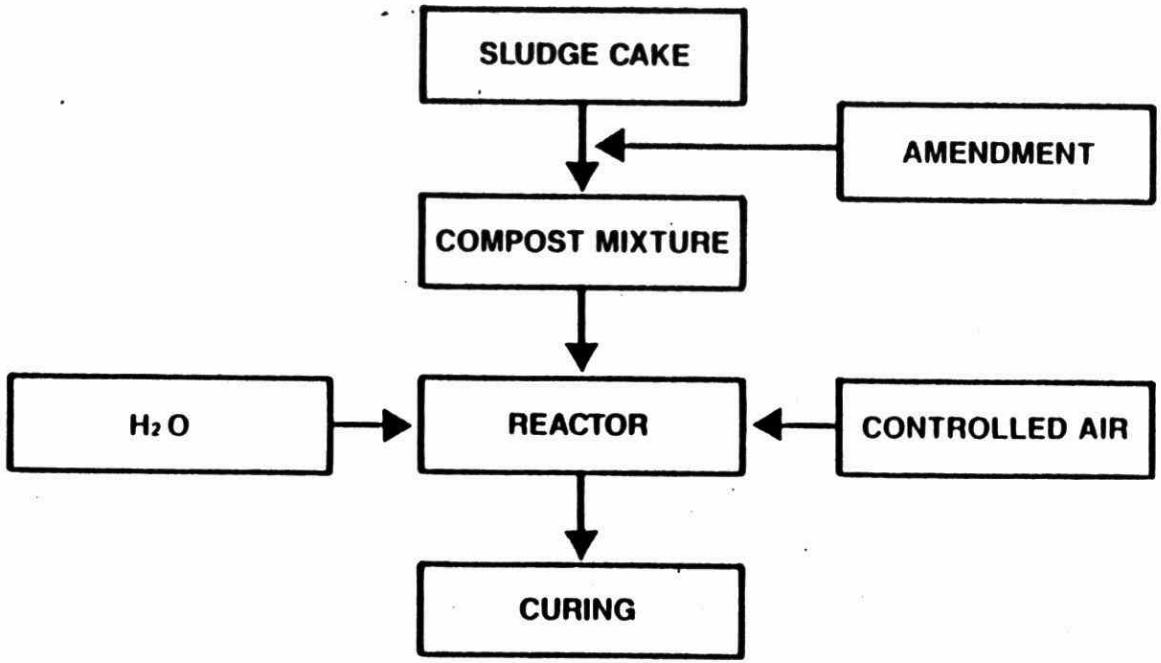
The provisions of high rate processes must be discussed in two categories. These provisions that are components of the compost system proper (e.g: amendment addition, controlled air flow) and those that support the operation of composting to provide a complete and operable system (e.g: sludge handling, nuisance control).

Compost Process Provisions

As can be concluded from the discussion of feedstock problems the ability to control the temperature in the high rate reactor is the single most important factor behind the performance of these systems. Proper operating temperature (60°-80°C) is the key to moisture reduction, volatiles reduction, and pathogen kill. What provisions of the high rate process, therefore, facilitate control of these parameters? The provisions are amendment addition and controlled air flow into the reactor. The relationship of the provisions to feedstock problems is described below.

Moisture Control. Reduction of moisture in the sludge cake feedstock is accomplished in the high rate system in two stages, as illustrated schematically in Figure 3. The first is the addition of amendment. The second is drying in the reactor by means of controlled air flow.

FIG. 3 MOISTURE CONTENT CONTROL



The addition of amendment is an excellent way to reconcile moisture content of the reactor feed. Not only does the drier amendment produce an overall lower moisture content in the mixture, but it increases the porosity of the feedstock to permit proper air distribution throughout the composting mass. Substances that have found use as amendment in high rate systems and their characteristics are presented in Table 2.

TABLE 2. TYPICAL HIGH RATE PROCESS AMENDMENTS

Item	Woodchips/ Sawdust	Paper Waste	Recycled Compost
Moisture (%)	15	10	30-40
Volatile Solids (%)	97	94	40
High Heating Value (Kcal/Kg)	4785	4200	2200
Elemental Analysis (% dry weight)			
C	48.3	45.4	24.0
H	6.0	6.1	2.4
O	42.4	42.1	11.0
H	0.3	0.3	2.0
S	0.1	0.1	0.6
Ash	2.9	6.0	60.0

It should be emphasized that the primary purpose of adding amendment in the high rate system is to condition the sludge and not to compost the amendment. In addition, since high rate systems are generally "in-vessel" or "reactor" systems, a structural amendment or bulking agent is not required.

Moisture content of the feedstock/amendment mixture is further reduced in the reactor through drying, which is a function of temperature and humidification as will be described in a later section of this paper.

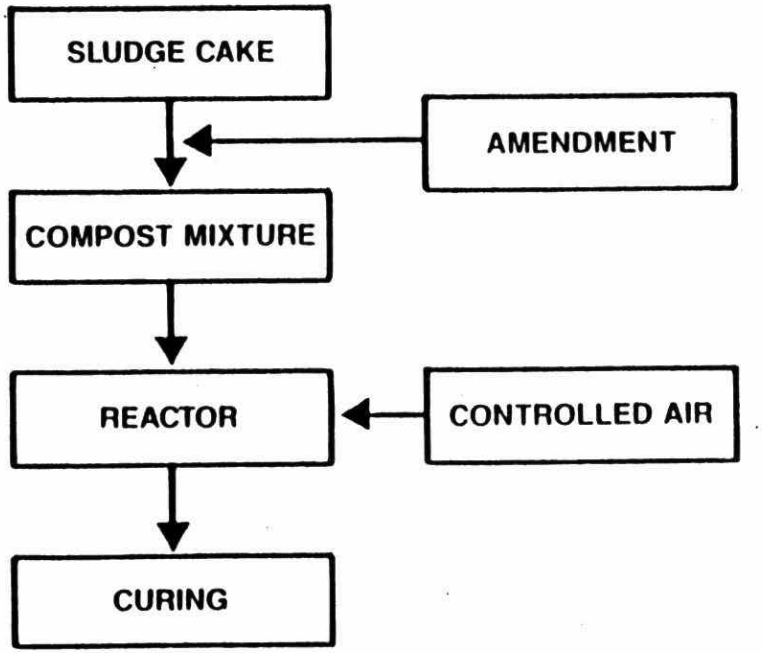
As can be observed from Figure 3, provisions to add moisture to the reactor are indicated. This concept seems contrary to the goals of composting since drying of the sludge is desired. As stated earlier, however, it is possible for low moisture content to limit operations due to the development of exessive temperature in the reactor. For this reason it is prudent to include the flexibility of adding moisture in the reactor.

Volatile Solids Control. Volatile solids reduction is accomplished by the biological oxidation which occurs in the reactor. This activity is intimately related to the moisture content of the mixture in the reactor and subsequently the operating temperature. For this reason the provisions utilized to control moisture content (amendment addition and controlled air flow) are essential for the control, of volatile solids content, as illustrated in Figure 4.

Pathogen Destruction. Pathogen destruction is a function of temperature and contact time. For a high rate process a temperature in the reactor of 55°C for a contact time of 3 days will assure pathogen kill. Therefore, as in the case of moisture and volatile solids control, the temperature in the reactor is the key element.

Control of Porosity. Initially porosity is adjusted by the addition of amendment to reconcile feedstock moisture. In the reactor porosity is increased by the drying which takes place. So in essence, low feedstock porosity is handled by dealing with moisture content and subsequently operating temperature in the reactor.

FIG.4 VOLATILE SOLIDS CONTENT CONTROL



Support System Provisions

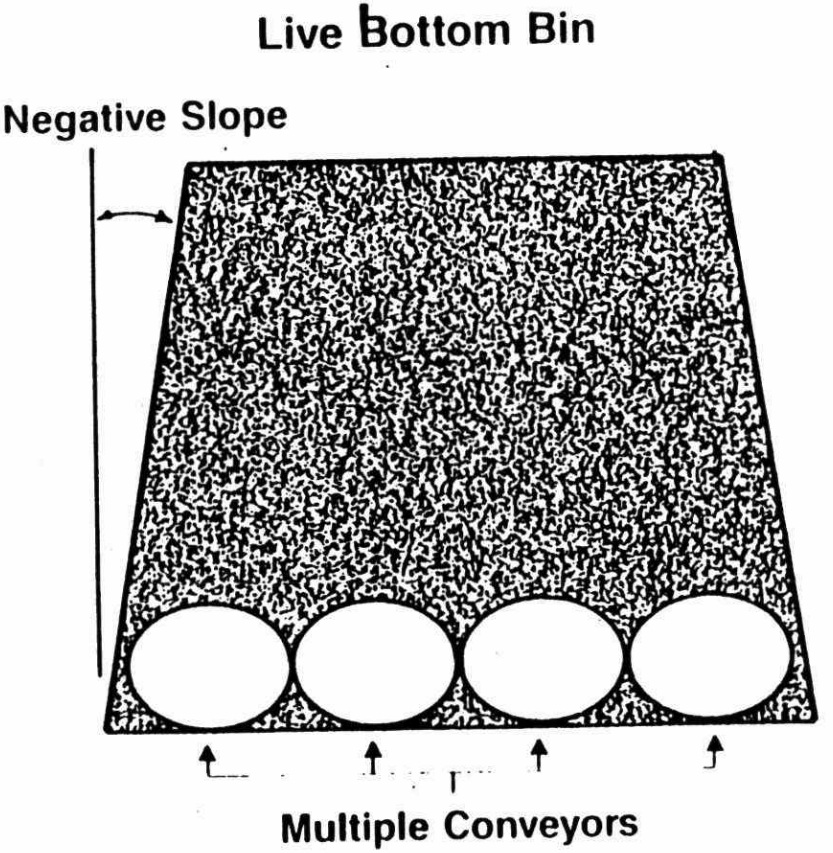
The two major support systems that accompany high rate systems are materials handling and nuisance control. It should be emphasized that these support systems are by no means unique to high rate systems. They warrant discussion, however, to complete the picture of the high rate system.

Materials Handling. Materials handling systems provide the storage, retrieval, and conveyance functions for the feedstock, amendment, and product or recycle compost. In general conveyance of sludge cake, compost mixture, and product compost is within the realm of standard trough conveyors commonly found in the wastewater field. On the other hand, storage and retrieval of such materials can be quite troublesome with the feedstock sludge cake being the most difficult of all. For this reason storage will be briefly discussed.

Sludge cake storage is commonly provided as the interface between the dewatering and composting operation. It can provide for varying process production rates as well to dampen surges. Dewatered sludge cake will compact while in storage as well as bridge in the hopper and prevent easy retrieval. Amendment and product compost may exhibit this problems to a lesser degree due to lower moisture contents. To eliminate problems with bridging and compaction, storage design should be based on hopper configurations as illustrated in Figure 5. Such hoppers incorporate live bottoms, negative (outward) slopes on all sides, and low height to width ratios. Configuration such as these have demonstrated a reliable track record on dewatered sludge as well as amendment or product compost.

Nuisance Control. The primary nuisance problem is the odor potential of the sludge cake. The exhaust gas from the high rate reactor can be moisture ladden as well as odorous. Several

FIG. 5 SLUDGE CAKE STORAGE CONFIGURATION



techniques, as will be described hereinafter, are applicable to odor control.

HIGH RATE COMPOST PROCESS COMPONENTS

Having identified, in a general manner, the problems posed by the feedstock, the provisions of the high rate process, and the key process control parameters an overall high rate process schematic can be developed, as illustrated in Figure 6. This schematic depicts the compost process components as well as the support systems required to provide a complete and operable system.

The remaining sections of this paper discuss in more detail the process variables to be considered in the design of a system, process control concerns, and nuisance control.

HIGH RATE COMPOST PROCESS DESIGN CONSIDERATIONS

Process variables for the high rate compost system are illustrated schematically in Figure 7. The process variables fall into two categories, thermodynamic and kinetic. The thermodynamic variables bear directly on process equilibrium, the kinetic variables on process rate.

Heat and Materials Balance. Heat and materials balances can be utilized to describe the high rate composting process. An example of a simplified heat and materials balance for a system handling a feed of 1000 lbs/hr of dry solids at 20 percent solids is presented in Figure 8. Based on this balance the following conclusions can be reached.

- The major use of heat energy in the composting process is for evaporation. Moisture content of the sludge can be the determining factor in choice of amendment. In the case of low moisture, high volatile

FIG.6 HIGH RATE MECHANICAL COMPOSTING PROCESS SCHEMATIC

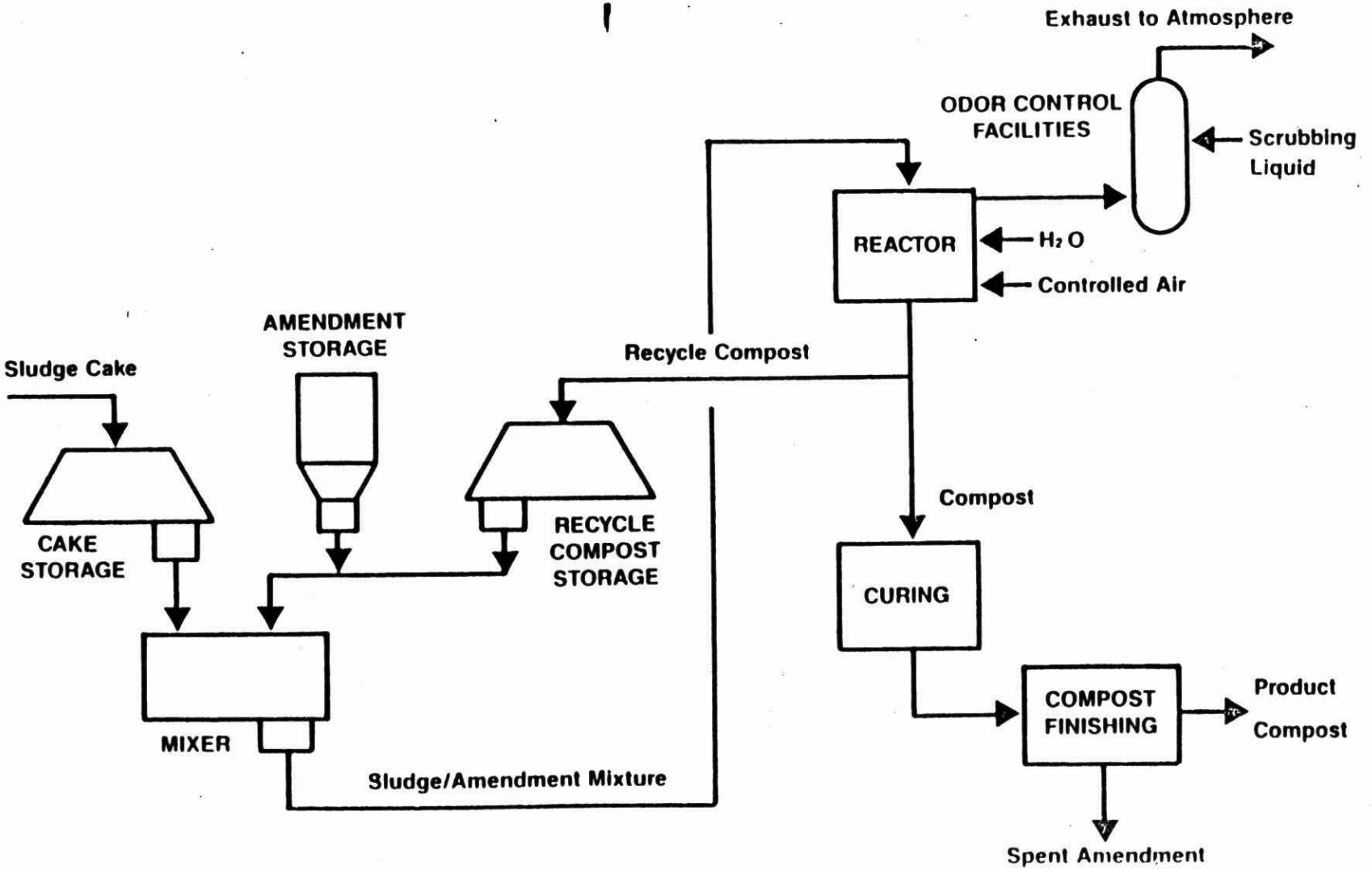


FIG. 7 PROCESS VARIABLES

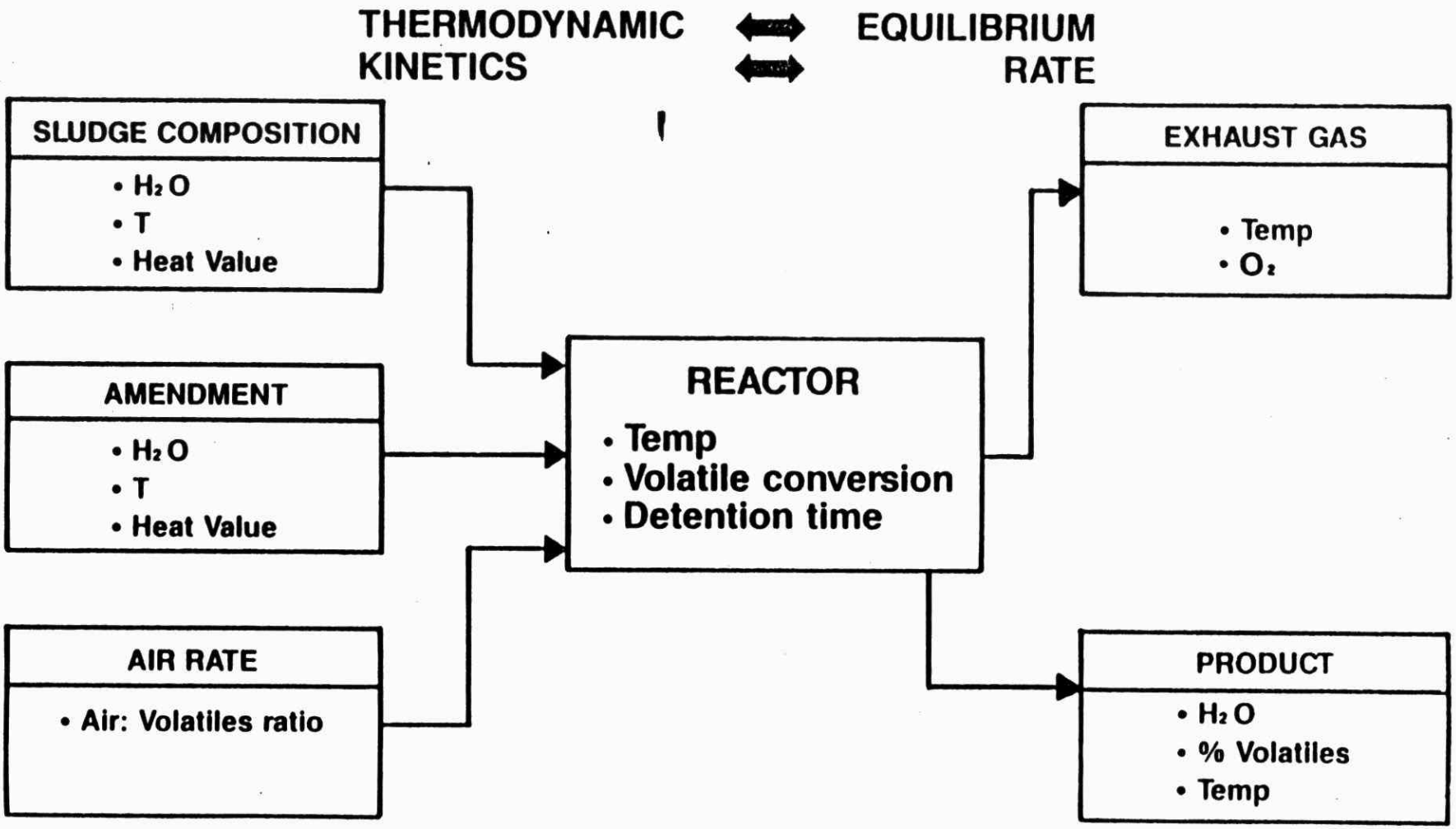
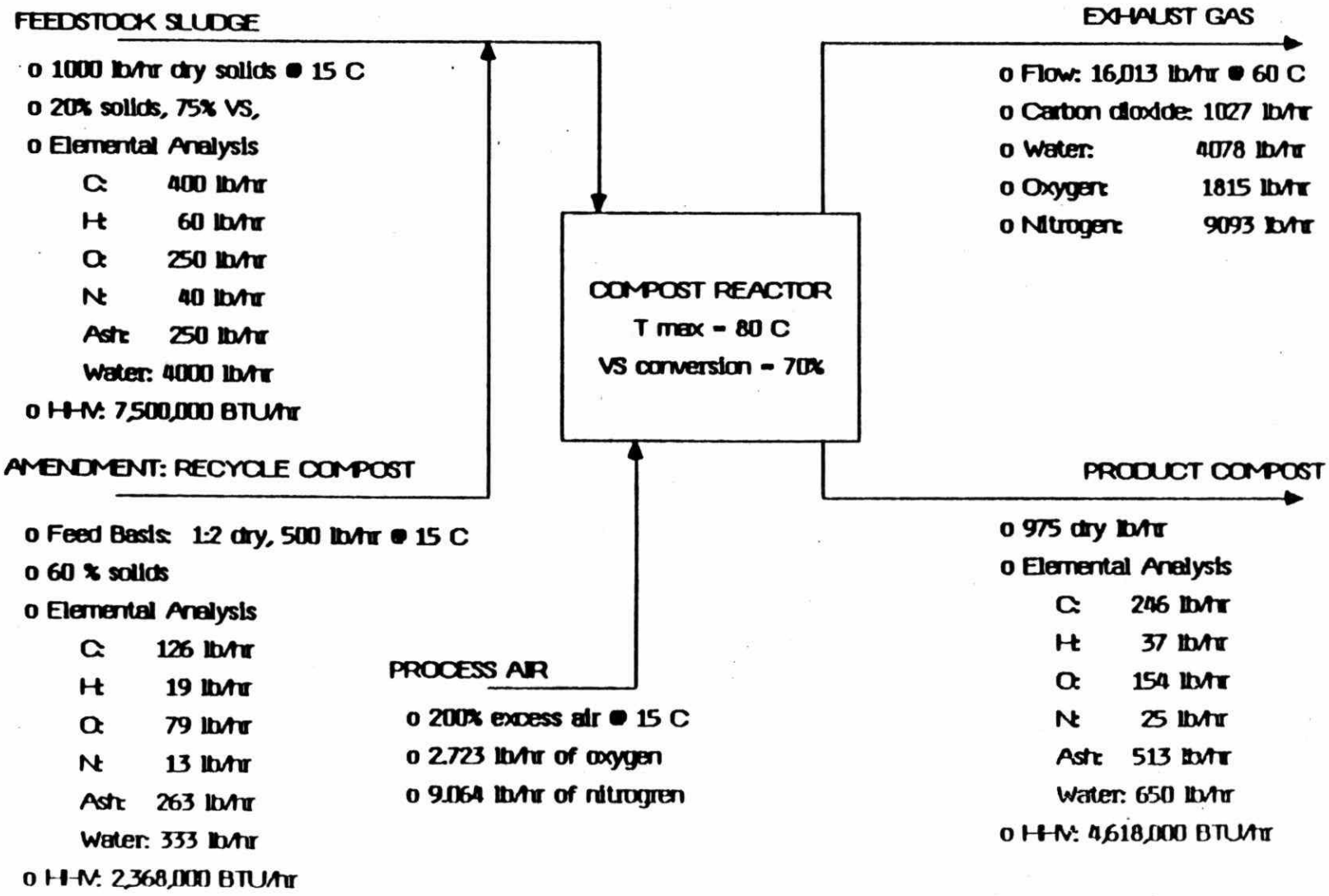


FIG. 8 HIGH RATE PROCESS PROCESS HEAT AND MATERIAL BALANCE



sludges, it may be necessary to add moisture to bring moisture into the range that air flow rates can be used to effectively control the process.

- Except for low volatile or low moisture content sludges, it is not necessary to use amendments with usable heating value (such as woodchips) if air flow rates can be adequately controlled.

- From a heat balance standpoint, the primary process controls are the usable heat content of the amendment and the air flow rate. The heat content and moisture of the feedstock (sludge plus amendment) must be in the right range so that the compost reaction can proceed. Process air flow rate can then be adjusted to yield the optimum reactor temperature (in the 60°-80°C range). Addition of too much amendment can be avoided by monitoring exhaust gas (O_2) concentration. If O_2 in the exhaust gas exceeds about 16% (300% excess air) on a moisture-free basis, too much amendment is being added.

- Feed and air temperature have only minor effects on the balance. Reduction of ambient temperature from 15°C to -15°C increases the usable heat needed by less than 20%, which can be made up by reduced sludge moisture content or use of amendments with usable heating valve. Composting of sludge is, therefore, feasible even in very cold climates.

Rate Considerations

In addition to the thermodynamic (equilibrium) considerations discussed above, kinetic (rate) conditions play an important part in the design composting processes, particularly

in the areas of unit sizing and organic conversion.

Two mechanisms are involved in determining the rate of the processes: evaporation and oxidation. Both are dependent on temperature and humidification. To optimize the activity of the microorganisms in the composting reactor, the maximum temperature in the reactor must be maintained within a relatively narrow range, typically 60°-80°C. Process air flow, and therefore drying rate, have much more of an effect on rate. The higher the air flow rate, the faster the drying process, and the less detention time needed to attain a given product moisture content. This is accomplished, however, at the penalty of additional amendment usage.

Process Control

The above discussion points out the two areas of most importance in designing and operating a high rate composting system: (1) heat and material balances; and (2) rate considerations. The relation of these factors to process control is discussed below. A basic process control schematic is illustrated in Figure 9.

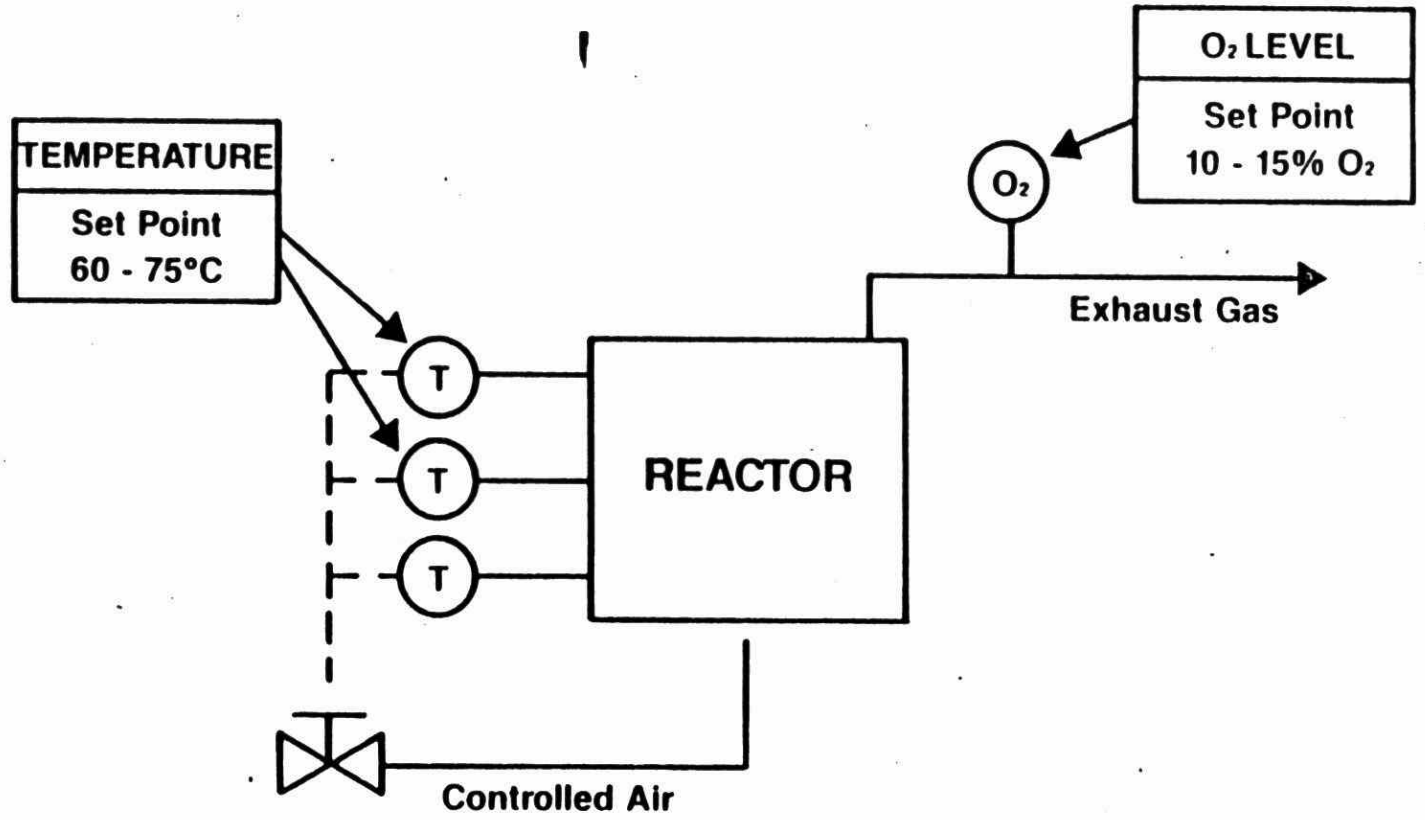
Objectives. Control of the composting process must accomplish the following objectives:

- The compost product must be stable and free of pathogens. This objective is accomplished by insuring sludge is composted at above 55C for a given length of time, usually 2-4 days.

- The process operation must be cost-effective with a minimum of expensive amendment use.

- Exhaust gas from the process must be odor free.

FIG. 9 PROCESS CONTROL SCHEMATIC



Heat and Material Balances. Heat and material balances should be used to insure that feed to the composting reactor is compostable, that is that heat input and outputs can be balanced somewhere in a relatively wide range of process air flows. This is accomplished by adding the proper proportion of amendment as well as taking into consideration sludge moisture and volatile content. (For low moisture, high volatile sludges, this factor may cause the addition of moisture, rather than amendment).

Another important heat and material balance consideration in operation of the high rate composting process is the moisture content of the feed sludge. It is important that the sludge be dry enough to exhibit enough structural rigidity that aerobic conditions can be maintained throughout the reactor, but not so dry as to inhibit the biological composting process. For most sludges, solids content of the reactor feed should be adjusted to 30-40 percent by addition of recycled compost.

Rate Considerations. Once sludge is in the reactor, composting rate is determined by the reactor temperature. Optimum composting occurs with a maximum temperature in the reactor in the 60°-80°C range. Significantly below 60°C, composting rate is slowed and pathogen kill cannot be assured. Above 80°C, reaction rate is also slowed, since the microorganisms responsible for the biological oxidation process do not survive.

Temperature in the reactor can be controlled by varying air flow rates. If temperatures are too high, air flow must be increased, to carry heat away from the reactor. Conversely, if temperatures are too low, air flow should be reduced, to retain more heat and increase temperatures.

NUISANCE CONTROL

The nuisance conditions associated with composting processes stem from several sources as listed below:

- o Odors
- o Dust
- o Vectors
- o Noise

Since high rate systems are in general "in vessel" systems odor potential is by for the most significant nuisance condition. For this reason only odor control will be discussed at this time.

Odor Control

Odor can be a problem in the high rate composting process. The compounds that are associated with odors are typically fatty acids, such as butyric, propionic, and acetic acids.

These compounds are naturally present in the sludge. Concentrations increse due to anaerobic activity. The first stage of the classical anaerobic digestion process includes conversion of complex organic molecules to fatty acids. For composting the following routes are available for control of these odor-causing compounds:

1. Prevent Formation
2. Sequestration
3. Removal from Exhaust

Prevention. If anaerobic activity is not allowed to proceed, fatty acids will not be formed. In composting,

prevention of formation must be accomplished both before and within the reactor. This can be done by insuring that all parts of the reactor are in an aerobic condition at all times, by maintaining adequate air flows and mixing rates.

Sequestrations. Odor causing compounds pass from the sludge phase to the gas phase by the process of evaporation (volatilization). Volatility coefficients of the salts of fatty acids are less than those of the fatty acids themselves. Therefore, addition of an alkaline chemical, such as lime or caustic soda, to the sludge can reduce odor emissions.

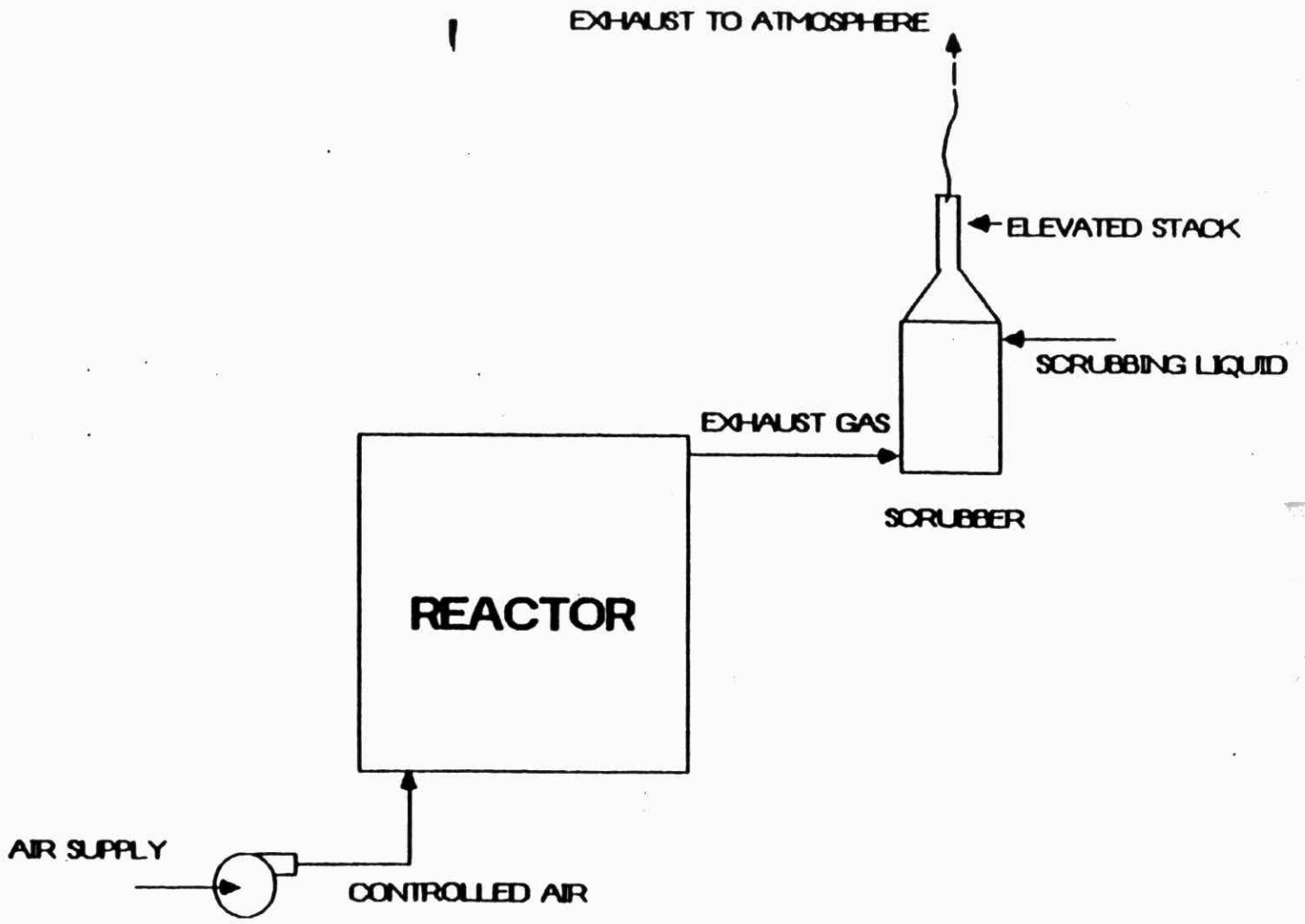
Removal. Odor causing organic compounds can be removed from the exhaust gas by oxidation. Chemical oxidation using sodium hypochlorite scrubbers has proven to be a viable control method for off-gases from composting.

Limited success had been experienced at operating installations utilizing finished compost as a scrubbing medium. Providing a separate means of odor control is prudent.

Atmospheric Dispersion. The dilution of odors through atmospheric dispersion can greatly enhance the operation of an odor control system. The use of an elevated stack for exhaust gases represents a point source emissions. Through proper location and selection of discharge elevation local atmospheric conditions can be used to provide large dilutions to supplement other odor control techniques.

Odor Management System. A schematic of a viable odor management system for a high rate system is illustrated in Figure 10.

FIG. 10 ODOR CONTROL METHODOLOGY



SUMMARY

The high rate compost process is a biological system which can be designed and controlled through the application of the laws of thermodynamics and reactor kinetics. The most critical process parameter to monitor and control is the operating temperatures in the reactor. The reactor operating temperature is intimately related to sludge cake feedstock moisture contents biological activity, porosity and air supply flow rate. Control of these high rate process variables through amendment addition, controlled air flow and, in some cases, agitation facilitate process operation and provide the capability to handle the problems associated with the feedstock sludge cake.

Utilizing Municipal Compost in Landscape Horticulture

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Abstract

Municipal waste compost produced by the Ontario Ministry of the Environment was used as a source of soil organic matter for nursery stock production and as a mulch for recently planted trees in an operational and partially rehabilitated gravel pit. In spite of a high pH, high soluble salts and elevated levels of some heavy metals compost was a good source of organic matter for tree and shrub production. As a mulch compost was effective in reducing plant losses and increasing growth.

Introduction

As acceptable landfill sites are more difficult to find municipalities are turning to recycling and composting as alternatives for their waste (3, 7). Potential markets for compost exist in horticulture where large quantities of organic matter are used.

Horticultural cropping systems are very site intensive thus organic matter is readily depleted. In field production manure has been a common organic amendment however, growers find that manure is expensive and not readily available. Organic materials are important in greenhouse and outdoor container production since many media contain no soil. Container production of landscape plants is a desirable method of using composted

waste materials since there is little threat of direct or indirect human consumption and only small amounts are eventually incorporated into the soil at planting time.

Organic materials are also very commonly used in landscaping. Although they often perform a decorative role their more important functions are conserving soil moisture and retarding rapid soil surface temperature fluctuation.

A major concern in using waste products is the occasionally high content of phytotoxic micronutrients (10) and elements (3,9). Growth and phytotoxicity responses to municipal compost have been reported for floricultural (2, 5) and vegetable (4, 10) crops. When used as a mulch, sewage-refuse compost reduced survival of nursery liners (11) but improved growth in a young stand of slash pine (1). As a container mix, sewage-refuse compost improved growth of some woody species (12) but caused chlorosis and reduced growth in other species (11). There is much information on the use of composted sewage sludge for woody and herbaceous species (6, 7) but very little has been published on the use of municipal compost without the addition of sewage as a container mix, soil amendment or mulch for woody plants.

This paper reports on two experiments carried out in 1982 and 1983 utilizing compost produced by the Centre for Resource Recovery in Downsview (Toronto), operated by the Ministry of the Environment. One experiment was initiated at Sheridan Nurseries Ltd., Glen Williams, to determine the feasibility of using compost as a source of soil organic matter for nursery stock production. A second experiment, undertaken

with TCG Materials Ltd., Aberfoyle assessed the use of compost as a mulch for recently planted trees in an operational gravel pit. Additional experiments carried out over several years, which assessed compost as a media amendment for container-grown nursery stock, are not reported here.

Experiment 1. Municipal Compost as a Source of Organic Matter for Field Grown Nursery Stock.

Methods

Beginning in early June 1982, 42 plots (1.25 m x 23m) were laid-out in a prepared sandy loam field of Sheridan Nurseries Ltd., Glen Williams. The field had been in roses for the 3 previous years and thus had received no organic matter during that time. Ministry of the Environment compost and horse manure was applied at each of 3 rates, 45, 90 and 180 tonnes/hectare (20, 40 and 80 tons/acre) with a tractor-drawn, drop-flail type manure spreader.

Immediately after application of compost or manure to the plots, a tractor-drawn rototiller incorporated and thorougly mixed the material in the plots to a depth of 25-30 cm. A v-shaped trench was drawn in the centre of each plot to facilitate planting.

On June 17 the following were planted: Juniperus chinensis 'Mountbatten', Mountbatten juniper; Taxus media, dense yew; Thuja occidentalis, pyramid white cedar; Prunus tomentosa, Manchu cherry; Syringa reticulata, Japanese tree lilac; Forsythia intermedia 'Beatrix Farrand', Beatrix Farrand forsythia; and Ligustrum vulgare 'Cheyenne', Cheyenne privet. The junipers and white cedars were 2 year liners, the yews were 3 year liners, the 2 tree species were 2 year seedlings, and the 2 shrubs were 60 cm and 40 cm respectively.

The area was laid-out as a blocked design with 6 replicates, 7 treatments (3 rates each of compost and manure, and an unamended plot) and with 5 plants of the 7 types in each plot. Each 23 m long plot

contained 45 plants spaced at 50 cm. Two hundred ten plants of each type were used, resulting in a total of 1,510 plants in the experiment

At planting time the soil was adequately moist. No irrigation or fertilizer was applied during either growing season. Soil samples were taken before and immediately after compost and manure incorporation then again in early October 1982 and 1983. These were analyzed for pH and the heavy metals Fe, Mn, Cu, Zn, Pb, Ni, Cd, and Co. In mid August 1982 and 1983 foliar samples were taken as mid-shoot leaves. They were analyzed for N, P, K, Ca, Mg as well as those heavy metals listed above. In early October 1982 the plants were evaluated using a numerical rating.

Winterburn of yew and white cedar was evaluated in May 1983. There were no treatment differences (data not shown). In July 1983 plants were visually evaluated for size, vigor and color. In October plants were cut off at ground level and prepared for dry weight measurement by stripping-off and discarding the leaves of deciduous species. Neither forsythia nor cherry were harvested. The forsythia were extremely similar and many of the cherry had died.

Results and Discussion

Observations through the 1982 growing season revealed very few differences among treatments. The deciduous shrubs in the unamended plots had a somewhat lighter green color than those in other plots. In October 1982 there were no significant differences in growth or quality among the 7 treatments for any of the species except privet (Table 1). Numerically, all rates of compost and manure produced better privet than the unamended treatment. Visual observations indicated that, in general,

plants in the compost treatments had somewhat higher ratings although the trend was not consistent. For several species the ratings increased slightly as the rate of compost increased but the differences were not significant. Neither compost nor manure at the highest rate had any adverse effect on the plants in spite of the high pH and initially high soluble salts levels:

	pH	Soluble salts (mhos x 10^{-5})
compost	7.8	365
manure	9.0	685

The high salts levels of the manure would have an adverse effect if used for germinating seed or recently rooted cuttings and may be phytotoxic on heavier, more poorly drained soil. Previous results with compost have shown its high salts are very readily leached, thus eliminating the potentially phytotoxicity.

During the 1983 season plants were visually evaluated (Table 2). No differences were evident for cherry or forsythia (data not shown). Differences among the other species were not very pronounced but some trends were evident. The high rate of manure reduced visual quality slightly for the three conifers. For juniper any amount of compost addition resulted in numerically better quality plants. White cedar n the unamended plots appeared best with quality decreasing somewhat as the

rate of either compost or manure increased. For yew a somewhat similar trend was evident exept that the low rate of compost exceeded the unamended plots. All compost and manure treatments significantly increased visual quality of privet compared to the unamended plots. There were no differences among any treatments for lilac.

Dry weight data of plants harvested in October 1983 (Table 3) revealed some treatment differences. The high rate of manure statistically or numerically reduced growth for the conifers. This is consistent with the belief that conifers are somewhat more susceptible to high salts than deciduous species. For juniper, as the rate of compost addition increased growth also increased although not significantly. Growth of white cedar in compost was generally better than in manure plots although none of the treatments were statistically different. For yew high rates of compost and manure suppressed growth somewhat. All compost and manure treatments numerically increased growth of privet compared to unamended plots. There were no differences in growth among any treatments for lilac.

In 1982 contents of some heavy metals (Pb in June, and Cu, Zn, Ni and Pb in October) in the soil plots containing compost (180 tonnes/ha) were significantly higher than in unmulched or manured plots (Table 4). In fact, levels were numerically higher for all heavy metals in June and October, except for Fe and Co. In 1983 the plots containing the high rate of compost had significantly higher levels of Cu, Zn, Ni and Pb than unamended plots (data not shown). There were no toxicity symptoms on plants growing in compost plots.

Levels of plant micronutrients and heavy metals were much higher in compost than in manure (Table 5). The macronutrients N, P, K and Mg were higher in manure. No visual injury symptoms were evident on any plants grown in compost or manure amended plots.

There were very few differences in levels of nutrients and heavy metals in the foliage of forsythia, cherry or yew plants grown in unamended, compost or manure plots in 1982 (Tables 6, 7, 8). The high rate of compost (180 tonnes/hectare) resulted in significantly or numerically higher levels of Cu, Zn, B and Ni in forsythia, Zn in cherry and Cu, B and Ni in yew compared to the unamended or manure treatments. Levels of Mo were less than 1 ppm in all instances.

In 1983 foliar levels of P, K, Cu and B (data not shown) were highest in forsythia plants grown in the high rate compst plots. A similar trend occurred for P, K and Zn in privet and P, K, Cu, Zn, B and Ni in yew. Levels of all plant nutrients were within those considered acceptable for growth, with the exception of N in forsythia and privet. Both of these fast growing shrubs were somewhat deficient in N because no fertilizer was applied in 1982 or 1983 and levels of N in the compost had diminished.

From these data it is evident that the addition of as much as 180 tonnes/hectare of compost or manure had no significantly beneficial or detrimental effect on plant nutrient level. Also, there was no observed detrimental effect of the elevated levels on plant growth or quality because the high levels of those plant nutrients listed above were well within an acceptable range for nursery stock (8).

Experiment 2. Municipal Compost as a Planting Mulch Within an Operational and Partially Rehabilitated Gravel Pit.

Methods

Several areas within the property of TCG Materials Ltd., Aberfoyle, were selected for treatment in May 1982. All areas were rehabilitated slopes with existing tall grass cover. One year seedlings of Acer saccharinum (silver maple), Populus x canadensis 'Eugenei' (Carolina poplar) and Robinia pseudoacacia (black locust), planted in early May 1982, occupied much of the treated areas. Also present in two areas were larger silver maple (200 cm tall) planted in single rows in the spring of 1981. Four treatments were applied to 29 single plant replicates of poplar and locust, 30 replicates of small silver maple and 15 replicates of large silver maple. The four treatments were: 1) control, 2) compost mulch, 3) herbicide plus compost mulch and 4) herbicide. One bushel (35 litres) of compost was placed in a circle 15 cm deep around all trees with the exception of the large maples which received 2 bushels (70 litres). Compost was reapplied to the large maples in May 1983. Roundup (glyphosate) herbicide was sprayed around the base of herbicide treated trees using a guard to protect the trees.

All areas contained extensive tall grass cover. Prior to treatment the trunk diameter at 15 cm above the ground was measured for the large silver maples. Soil samples were collected prior to treatment and again in mid September 1982 for analysis of the heavy metals Fe, Mn, Cu, Zn, Pb, Ni, Cd, Co. Foliar samples were collected in mid August for analysis

of N, P, K, Ca, Mg as well as the heavy metals. In mid September the length of all the current season's growth was measured on all plants. Trunk diameter was also measured on the large maples. The 1983 sampling consisted of foliar samples from the large maples and measuring the length of current season's growth on all plants. Trunk diameter was also measured on the large maples.

Results and Discussion

Six weeks after the treatments were applied in 1982 several differences were evident. Untreated trees had extensive weed growth at their base. In some plots weeds such as wild carrot, plantain and quack grass were growing through the compost where no herbicide was used under the mulch (Fig. 1a). No weeds were evident in the herbicide plus compost treatment (Fig. 1b). For the herbicide treatment very few weeds were growing. Leaves of untreated trees and those of the compost treatment where weeds were growing through had a much lighter green color. This was most evident for the large and small maples. Thus weed control, whether with mulch or herbicide, was important. There was no visual difference in foliage color between the herbicide plus compost and herbicide treatments.

The 1983 observations regarding weeds and leaf color were similar to 1982. The summer of 1983 was very dry. During the growing season treatment differences were very obvious. For the small maples several unmulched and herbicide only treated plants died as a result of drought stress. Compost treated plants, particularly those with both herbicide and mulch, rarely wilted or died. Several of the large maples in areas 3

and 4 either unmulched or herbicide only treated were wilted during the dry period also.

Growth analysis measurements revealed differences among some treatments in 1982 (Table 9). For all trees the herbicide plus compost and herbicide treatments resulted in numerically greater growth than the unmulched and compost treatments. Statistically, the same relationship held in only one instance. With 4 of the 6 trees growth in the herbicide plus compost treatment was numerically greater than in the herbicide treatment. However, this superiority was statistically significant for only 1 group of maples. The herbicide treatment resulted in the best growth of the large maples and the black locust. Trees treated with compost grew numerically but not significantly more than unmulched trees. Some of the large maples were the only trees in which there were no significant differences among any of the treatments. These trees grew poorly and were the most variable of all. From the data it is clearly evident that weed control was important. Conserving moisture for tree growth on this dry site was critical. The data also indicate that compost in addition to weed control may be beneficial.

Shoot growth of plants in all areas in 1983 was numerically and in most cases significantly greatest for the herbicide plus mulch treatment (Table 10, Fig. 2,3). In the dryest parts of the site where the soil is the "poorest" shoot growth was numerically greater with mulch than with herbicide. This again stresses the importance a mulch on dry sites during drought stress periods.

Trunk diameter in 1983 for the large maples (area 4) was

significantly greater with herbicide plus mulch than with no treatment (Table 11). Trees with mulch or herbicide alone were numerically intermediate between herbicide plus compost and untreated plants. In area 3 which was dry and infertile trunk diameter was similar for untreated, mulched and herbicide treated trees but sifnificantly less than compost plus herbicide.

These results indicate the importance of a mulch during a dry season on a dry, very well drained site. A possible reason for improved performance of mulched and/or herbicide treated plots may have been greater root growth during periods of low stress. Having a more extensive root system would be an obvious benefit during a drought. In 1982, which was not so dry, the control of weed competition was as much or more important than mulch (Table 9). Since treatments were not re-applied in the spring of 1983 to any of the seedlings planted in 1982 the growth effects were a carry-over from the previous year.

Soil below the herbicide plus compost mulch treatment in 1982 did not contain significantly greater levels of heavy metals than the unmulched soil (Table 12). The reverse was the case in area 2 for Cu and Zn. From the data it appears that using a compost mulch did not increase heavy metal content in the soil.

Differences in leaf element content occurred in the large silver maples in 1982 (Table 13). The highest N and K levels were in herbicide plus compost and least in unmulched treatments. In both instances herbicides plus compost resulted in higher element levels than compost or herbicide alone. This indicates that weed control and compost

application were beneficial. In some instances weed control was as beneficial as compost. High B levels were recorded for the compost treatments. Levels of Mo were less than 1 ppm in all instances. Compost soluble salts were 165 mhos x 10^{-5}, pH was 8.0.

Foliar analysis of the large silver maples in 1983 revealed results somewhat similar to those in 1982 (Table 13). Both N and K were numerically highest in the compost plus herbicide treatment. Boron was again highest in the two compost treatments. All untreated trees were a very light green color.

A difference in color between mulched and unmulched plants was very pronounced for silver maple seedlings. Unmulched trees were lower in N, P and K (data not shown). Again, B was high in mulched trees as were levels of Ni, Cd and Co.

Mulch and/or herbicide altered some nutrient and heavy metal levels in black locust and Carolina poplar seedlings in 1982 (data not shown). In general, the compost and/or herbicide plus compost increased N, K, B and Cr content compared to the herbicide and unmulched treatments. The trend for Mn, Zn and Fe was not significant. The only visual difference in the field for these two species was a somewhat lighter green leaf color for unmulched plants. The most striking increase as the result of compost mulch was in B.

Growth and foliar analysis data reveal that the increased nutrient content provided by the compost and the herbicide weed control was beneficial for early establishment and growth of trees on rehabilitated sites. In general, compost was beneficial for some increased nutrient

content while compost and/or herbicide was beneficial for increased growth.

Conclusions

Experiment 1. Compost was easy to work with and did not have the objectionable odor of manure. Both compost and manure addition to soil plots resulted in slightly darker green leaves of deciduous shrubs during the first growing season. Very slight trends were observed for increased growth and quality for compost treatments, and as compost incorporation rate increased. The highest rates of compost and manure addition (180 tonnes/ha or 80 tons/acre) did not adversely affect plant growth in spite of the fact that both types of organic matter had high soluble salts. There was a trend to a greater weed populatin in manured plots and as application rate increased compared to compost plots. The highest rate of compost had little effect in increasing nutrient or heavy metal levels in plant tissue during the first year. In the second year the high rate resulted in higher levels of several elements. Any elevated levels of plant nutrients were within an acceptable range. Addition of high rates of compost increased levels of many heavy metals in the soil. No phytotoxicity was observed.

Experiment 2. In many instances herbicide plus compost mulch resulted in significantly more growth compared to untreated trees. Reduced weed competition with herbicide or mulch increased growth and quality of trees. During a very dry season mulch was more beneficial than weed

control. Compost mulch alone was not a very effective weed control. Compost mulch and/or herbicide plus compost mulch treatments generally increased the content of some nutrients and heavy metals in trees. No phytotoxicity resulted. Soil below compost mulch did not contain significantly higher levels of heavy metals.

LITERATURE CITED

1. Bengsten, G.W. and J.J. Cornett. 1973. Disposal of composted municipal sludge in a plantation of young slash pine; Effects on soil and trees. J. Environ. Qual. 2:441-444.

2. De Vleeschauwer, D., O. Verdonck and M. DeBoodt. 1980. Use of town refuse compost in horticultural substrates. Acta Hort. 99:149-155.

3. El Bassam, N. and A. Thorman. 1979. Potentials and limits of organic wastes in crop production. Compost Sci./Land Utilization 20:30-35.

4. Frey, D.R. 1981. Composted solid waste and its use for germinating seeds. Plant Propagator 27(3):10-11.

5. Gogue, G.J. and K.C. Sanderson. 1975. Municipal compost as a medium amendment for chrysanthemum culture. J. Amer. Soc. Hort. Sci. 100:213-216.

6. Gouin, F.R. 1977. Conifer tree seedlings response to nursery soil amended with composted sewage sludge. HortScience 12:341-342.

7. Gouin, F.R. 1980. Introduction to the symposium: Using municipal and agricultural waste for the production of horticultural crops. HortScience 15:161-162.

8. Lumis, G.P. 1974. Foliar nutrient content of woody ornamentals. Landscape Ontario 2(3):20, 22, 28.

9. Lumis, G.P. and A. G. Johnson. 1982. Boron toxicity and growth suppression of Forsythia and Thuja grown in mixes amended with municipal waste compost. HortScience 17:821-822.

10. Purves, D. and E.J. MacKenzie. 1973. Effects of applications of municipal compost on uptake of copper, zinc and boron by garden vegetables. Plant and Soil 39:361-371.

11. Sanderson, K.C. 1980. Use of sewage-refuse compost in the production of ornamental plants. HortScience 15:173-178.

12. Sanderson, K.C. and W.C. Martin Jr. 1974. Performance of woody ornamentals in municipal compost medium under nine fertilizer regimes. HortScience. 9:242-243.

Table 1 Ratings of growth and quality among 7 species planted in soil plots amended with varying rates of compost and manure (1982).

Treatment	Juniper	Yew	White cedar	Cherry	Lilac	Forsythia	Privet
Unamended	2.6	2.8	2.7	2.6	3.0	3.0	2.2 b
Compost 1	2.5	2.4	1.8	2.3	2.6	2.8	2.7 ab
Compost 2	2.5	2.5	2.3	2.4	2.6	2.8	2.4 ab
Compost 3	2.7	2.3	2.3	2.9	2.8	2.7	2.5 ab
Manure 1	2.3	2.8	2.1	2.3	2.7	2.8	2.8 ab
Manure 2	2.1	2.3	2.1	2.7	2.6	2.8	2.9 a
Manure 3	2.6	2.2	2.0	2.3	2.7	2.9	2.3 ab
	ns	ns	ns	ns	ns	ns	

application rates: 1, 2, 3 = 45, 90 and 180 tonnes/hectare (20, 40 and 80 tons/acre) respectively.

rating: 1 = limited shoot growth, leaves small and with light green colour; 2 = moderate shoot growth, leaves normal size and colour; 3 = extensive shoot growth, leaves normal size and with deep green colour.

values an average of 6 replicates; mean separation for privet by Duncan's multiple range test, 5% level.

Table 2 Ratings of quality for 5 species during the second year of growth in soil plots amended with varying rates of compost and manure (1983).

Treatment	Juniper	Yew	White cedar	Lilac	Privet
Unamended	1.4 ab	1.8 ab	1.8 a	2.1	0.9 b
Compost 1	1.9 a	2.0 a	1.7 a	1.4	2.2 a
Compost 2	1.9 a	1.5 ab	1.3 ab	2.1	1.6 a
Compost 3	2.0 a	1.6 ab	1.3 ab	1.7	1.9 a
Manure 1	1.8 ab	1.5 ab	1.2 ab	1.8	2.0 a
Manure 2	1.4 ab	1.4 ab	1.0 ab	2.1	2.0 a
Manure 3	1.2 b	1.1 b	0.8 b	1.4	1.9 a
				ns	

application rates: 1,2,3 = 45, 90 and 180 tonnes/hectare (20, 40 and 80 tons/acre) respectively

rating: 1 = plants small, least shoot growth; 2 = plants intermediate, moderate shoot growth; 3 = plants large, most shoot growth.

values an average of 6 replicates; mean separation in columns by Duncan's multiple range test, 5% level.

Table 3 Top dry weight (g) of 5 species grown for 2 years in soil plots amended with varying rates of compost and manure (1983).

Treatment	Juniper	Yew	White cedar	Lilac	Privet
Unamended	38.5 bc	58.6 a	116.5	77.6	195.5 b
Compost 1	50.3 ab	55.2 ab	82.6	74.0	227.8 ab
Compost 2	53.7 ab	61.3 a	112.3	85.1	214.5 ab
Compost 3	57.1 a	51.9 ab	91.3	74.0	250.6 ab
Manure 1	40.8 abc	57.1 a	78.8	65.5	269.2 ab
Manure 2	30.3 c	58.5 ab	81.8	78.2	293.0 a
Manure 3	31.8 c	43.2 b	68.8	78.6	261.6 ab
			ns	ns	

application rates: 1,2,3 = 45, 90 and 180 tonnes/hectare (20, 40 and 80 tons/acre) respectively

values an average of 6 replicates; mean separation in columns by Duncan's multiple range test, 5% level.

Table 4 Heavy metals content in soil samples from compost incorporation trial at Sheridan Nurseries (1982).

Sampling time	Treatment	Mn	Cu	Zn	Fe	Ni	Pb	Cd	Co
June	Unamended	446	10.1	31	12,459	8.8	10.5bc	.2	3.6
	Compost 1	289	20.2	82	8,706	8.7	16.5b	.3	2.7
	Compost 3	366	18.6	162	10,773	10.1	25.5a	.6	3.3
	Manure 1	289	4.6	41	7,947	7.5	6.0c	.1	2.3
	Manure 3	285	4.5	16	7,891	7.5	4.8c	.1	2.3
		ns	ns	ns	ns	ns		ns	ns
October	Unamended	189	0.9b	10b	5,175	6.5b	2.8b	.1	1.6
	Compost 1	208	8.4b	19b	7,609	7.9ab	7.3b	.1	2.6
	Compost 3	247	15.6a	55a	6,852	9.1a	20.3a	.1	2.0
	Manure 1	215	3.1b	14b	6,709	7.1b	2.8b	.1	2.0
	Manure 3	227	2.1b	12b	6,312	6.7b	2.8b	.1	1.8
		ns			ns			ns	ns

values reported in µg/g of soil, averaged for 4 replicates; mean separation in columns by Duncan's multiple range test, 5% level

Table 5 Nutrient and heavy metal analysis of compost and manure used for soil incorporation at Sheridan Nurseries.

Treatment	N	P	K	Ca	Mg	Mn	Cu	Zn	B	Fe	Ni	Pb	Cr	Cd	Co
	%					ppm									
Compost	.93	.21	.37	4.2	.45	583	622	622	*	8,040	158.1	765.0	217.0	6.8	11.2
Manure	2.2	.50	3.15	3.15	.93	224	224	19	*	1,873	3.9	7.3	4.3	0.6	1.2

values an average of 3 replicates

*invalid results due to interference by high Fe

Table 6 Nutrient and heavy metal levels in leaves of forsythia plants grown in soil plots amended with varying rates of compost and manure (1982).

Treatment	N	P	K	Ca	Mg	Mn	Cu	Zn	B	Fe	Ni	Pb	Cr	Cd	Co
	%					-ppm-									
Unamended	2.2	.2	1.2	.9	.1	84	5	9.0b	31	60	.38	2.2	1.1	.3	.59
Compost 1	2.2	.2	1.5	.9	.1	90	6	12.3a	36	63	.58	2.2	1.2	.2	.72
Compost 3	2.2	.2	1.6	.8	.1	93	10	13.3a	55	65	.50	2.9	1.3	.2	.79
Manure 1	2.1	.1	1.4	.8	.1	90	5	9.3b	31	62	.35	2.2	1.3	.2	.53
Manure 3	2.2	.2	2.1	.9	.1	88	5	9.7b	32	55	.34	2.2	1.2	.2	.86
	ns	ns	ns	ns	ns	ns	ns		ns	ns	ns	ns	ns	ns	ns

application rates 1 and 3 are 45 and 180 tonnes/hectare (20 and 80 tons/acre) respectively.

values an average of 3 replicates; mean separation by Duncan's multiple range test, 5% level.

Table 5 Nutrient and heavy metal analysis of compost and manure used for soil incorporation at Sheridan Nurseries.

Treatment	N	P	K	Ca	Mg	Mn	Cu	Zn	B	Fe	Ni	Pb	Cr	Cd	Co
	%					ppm									
Compost	.93	.21	.37	4.2	.45	583	622	622	*	8,040	158.1	765.0	217.0	6.8	11.2
Manure	2.2	.50	3.15	3.15	.93	224	224	19	*	1,873	3.9	7.3	4.3	0.6	1.2

values an average of 3 replicates

*invalid results due to interference by high Fe

Table 6 Nutrient and heavy metal levels in leaves of forsythia plants grown in soil plots amended with varying rates of compost and manure (1982).

Treatment	N	P	K	Ca	Mg	Mn	Cu	Zn	B	Fe	Ni	Pb	Cr	Cd	Co
	- - - - - - - - % - - - - -					- - - - - - - - - - - - - - - - - - -ppm- - - - - - - - - - - -									
Unamended	2.2	.2	1.2	.9	.1	84	5	9.0b	31	60	.38	2.2	1.1	.3	.59
Compost 1	2.2	.2	1.5	.9	.1	90	6	12.3a	36	63	.58	2.2	1.2	.2	.72
Compost 3	2.2	.2	1.6	.8	.1	93	10	13.3a	55	65	.50	2.9	1.3	.2	.79
Manure 1	2.1	.1	1.4	.8	.1	90	5	9.3b	31	62	.35	2.2	1.3	.2	.53
Manure 3	2.2	.2	2.1	.9	.1	88	5	9.7b	32	55	.34	2.2	1.2	.2	.86
	ns	ns	ns	ns	ns	ns	ns		ns	ns	ns	ns	ns	ns	ns

application rates 1 and 3 are 45 and 180 tonnes/hectare (20 and 80 tons/acre) respectively.

values an average of 3 replicates; mean separation by Duncan's multiple range test, 5% level.

Table 7 Nutrient and heavy metal levels in leaves of Manchu cherry plants grown in soil plots amended with varying rates of compost and manure (1982).

Treatments	N	P	K	Ca	Mg	Mn	Cu	Zn	B	Fe	Ni	Pb	Cr	Cd	Co
	%					ppm									
Unamended	2.7	.2	1.5	1.0	.1	43	6	13	32	247	1.1	3.2	2.1	.3	1.2
Compost 1	2.7	.2	1.7	1.0	.1	48	7	13	28	244	1.2	3.1	2.1	.3	1.1
Compost 3	2.6	.2	2.0	1.0	.1	44	7	17	33	192	1.0	2.9	2.1	.3	1.0
Manure 1	2.7	.2	2.0	1.0	.1	46	7	14	30	227	1.1	3.3	2.0	.3	1.0
Manure 3	2.9	.2	2.2	0.8	.1	35	7	15	27	216	1.0	3.4	2.1	.2	1.2
	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

application rates 1 and 3 are 45 and 180 tonnes/hectare (20 and 80 tons/acre) respectively.
values an average of 3 replicates; mean separation by Duncan's multiple range test, 5% level.

Table 8 Nutrient and heavy metal levels in leaves of yew plants grown in soil amended with varying rates of compost and manure (1982).

Treatment	N	P	K	Ca	Mg	Mn	Cu	Zn	B	Fe	Ni	Pb	Cr	Cd	Co
	----------%----------					----------ppm----------									
Unamended	1.7	.17	1.01c	.9	.1	23	4	13	22bc	188	.60	1.7	1.3	.2	.43
Compost 1	1.7	.16	1.08bc	.9	.1	33	4	14	27b	190	.60	.7	1.2	.2	.70
Compost 3	1.4	.16	1.19ab	.9	.1	29	4	13	33a	126	1.07	1.4	1.2	.2	.92
Manure 1	1.6	.17	1.07bc	.9	.1	33	4	14	21c	135	.46	.7	1.2	.2	.63
Manure 3	1.6	.17	1.27a	.9	.1	28	5	17	23bc	152	.44	.6	1.2	.2	.57
	ns	ns		ns	ns	ns	ns	ns		ns	ns	ns	ns	ns	ns

application rates 1 and 3 are 45 and 180 tonnes/hectare (20 and 80 tons/acre) respectively.
values an average of 3 replicates; mean separation by Duncan's multiple range test, 5% level.

Table 9 Growth of tree species on several sites within an operational and partially rehabilitated gravel pit, in response to compost mulch and herbicide weed control (1982).

Tree species and location	Total shoot length (cm)			
	Unmulched	Compost	Herbicide plus compost	Herbicide
Silver maple area 2a	42 b	30 b	112 a	64 ab
Silver maple area 2b	18 b	23 b	97 a	49 b
Silver maple area 3	140 a	149 a	326 a	166 a
Silver maple area 4	191 c	282 bc	374 b	572 a
Carolina poplar	35 c	49 bc	76 a	62 ab
Black locust	53 b	41 b	46 b	102 a

maples in areas 3 and 4 were of landscape size (200 cm) planted in 1981 while all other trees were planted in 1982 as 1 year old seedlings.

values an average of at least 5 replicates; mean separation in rows by Duncan's multiple range test, 5% level.

Table 10 Growth of tree species on several sites within an operational and partially rehabilitated gravel pit, in response to compost mulch and herbicide weed control (1983).

Tree species and location	Total shoot length (cm)			
	Unmulched	Compost	Herbicide plus compost	Herbicide
Silver maple area 2a	8 c	68 b	117 a	48 bc
Silver maple area 2b	18 b	32 b	107 a	19 b
Silver maple area 3	178 b	302 b	697 a	301 b
Silver maple area 4	219 b	720 a	1024 a	871 a
Carolina poplar	22 c	42 bc	197 a	106 b
Black locust	61 b	243 ab	376 a	223 ab

maples in areas 3 and 4 were of landscape size (200 cm) planted in 1981 while all other trees were planted in 1982 as 1 year old seedlings.

values an average of at least 5 replicates; mean separation in rows by Duncan's multiple range test, 5% level.

Table 11 Trunk diameter growth for trees on two sites within an operational and partially rehabilitated gravel pit, in response to compost mulch and herbicide weed control.

Treatment	Trunk diameter increase (mm)			
	Area 3		Area 4	
	1982	1983	1982	1983
Unmulched	.9 a	3.9 b	1.9 c	5.9 b
Compost mulch	1.4 ab	3.3 b	2.9 bc	8.6 ab
Herbicide plus compost mulch	2.6 ab	12.3 a	5.3 a	11.2 a
Herbicide	3.2 a	4.2 b	4.7 ab	9.8 ab

values an average of 5 replicates (area 3) and 10 replicates (area 4); mean separation in columns by Duncan's multiple range test, 5% level.

Table 12 Heavy metal content in soil samples from two areas and under two treatments within an operational and partially rehabilitated gravel pit, in response to compost mulch and herbicide weed control (1982).

Site	Treatment	Mn	Cu	Zn	Fe	Ni	Pb	Cd	Co
Area 1	Unmulched	570	4.5	169	7,889	9.2	80.3	.9	3.3
	Herbicide + compost mulch	629	4.9	156	10,815	8.6	59.3	.7	3.6
		ns	ns	ns	ns	ns	ns	ns	ns
Area 2	Unmulched	643	12.6a	183a	7,201	8.9	39.5	.8	3.4
	Herbicide + compost mulch	564	5.7b	148b	6,693	8.5	44.0	.8	3.2
		ns			ns	ns	ns	ns	ns

values reported in µg/g of soil, average for 4 replicates; mean separation in columns by Duncan's multiple range test, 5% level.

Table 13. Nutrient and heavy metal levels in leaves of silver maple trees within an operational and partially rehabilitated gravel pit, in response to compost mulch and herbicide weed control.

Year	Treatment	N	P	K	Ca	Mg	Mn	Cu	Zn	B	Fe	Ni	Pb	Cr	Cd	Co
		----------% ----------					----------% ----------									
1982	Unmulched	1.3c	.18	.42b	1.6	.51	56	7.5	45	46b	119	1.6a	10.5	2.8a	.14	.8
	Compost	1.7c	.17	.60ab	1.5	.49	59	5.8	46	61a	113	1.2ab	8.5	1.7b	.30	1.0
	Herbicide + compost mulch	2.0a	.16	.75a	1.1	.37	52	8.3	40	64a	105	.9bc	5.0	1.4bc	.14	.3
	Herbicide	1.6b	.15	.44b	1.1	.37	49	6.0	31	27b	83	.6c	5.7	.9c	.12	.4
			ns		ns	ns	ns	ns	ns		ns		ns		ns	ns
1983	Unmulched	1.9b	.17	.46b	2.0	.7	77	9	63	37b	332	.21	1.5	.13	.06	.31
	Compost	2.3a	.17	.67a	1.7	.6	84	6	77	175a	346	.21	1.4	.11	.06	.29
	Herbicide + compost mulch	2.5a	.18	.75a	1.8	.6	85	7	77	222a	302	.22	1.3	.11	.06	.30
	Herbicide	2.2a	.17	.47b	2.0	.7	98	6	55	34b	311	.20	1.4	.12	.06	.31
			ns		ns	ns	ns	ns	ns		ns	ns	ns	ns	ns	ns

Values an average of 4 or 6 replicates; mean separation in columns by Duncan's multiple range test, 5% level.



Fig. 1 a. Weed growth through compost mulch without herbicide pretreatment.

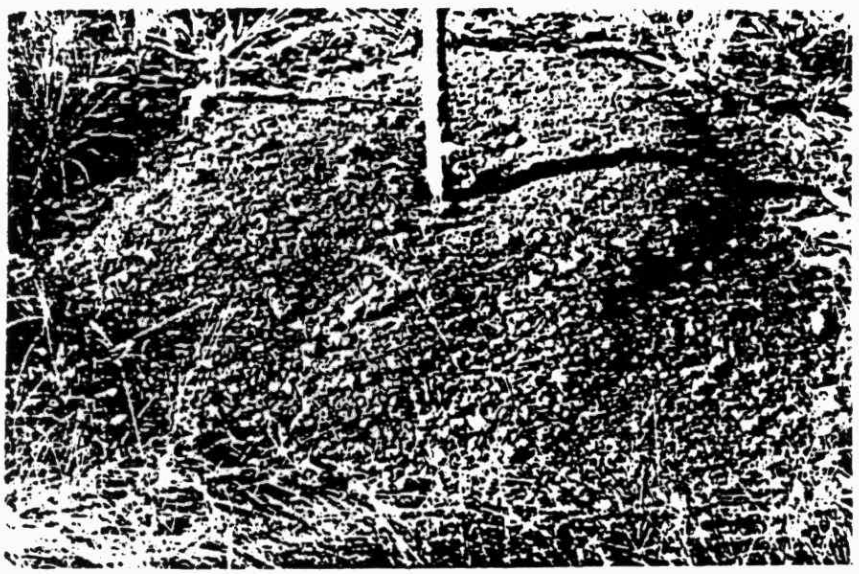


Fig. 1b. No weed growth through compost mulch with herbicide pretreatment.



Fig. 2. Growth differences of small maples (area 2) between treatments in a very dry season. Left = herbicide, right = herbicide plus mulch (1983).



Fig. 3. Growth differences of large maples (area 3) between treatments. Left = untreated, right = herbicide plus mulch (1983).

Economic Aspects of Composting Organic Wastes

by

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Organic Waste Disposal - Opportunities and Constraints

Organic wastes can be broadly defined as any by-products derived from living animal or vegetable organisms for which an economical use or market cannot be found. Frequently included under the heading of organic wastes are crop residues and livestock manures in agriculture, trimmings, chips, bark and sawdust in the forestry and allied industries, and sewage plus solid and liquid refuse from the urban-industrial sector.

Most organic wastes break down readily under bacteriological action, producing utilizable plant nutrients and organic matter useful for soil conditioning. Recycling organic wastes through the forestry, agricultural and horticultural industries represents the sole opportunity for putting these products to any good use.

As to whether organic wastes are used in this capacity depends a great deal on the associated economics, in terms of the costs of collecting, processing and land-applying or marketing the wastes versus the inherent value of the wastes as a source of plant nutrients and as a soil conditioner. Wherever handling costs exceed inherent values, recycling as an option may be constrained.

Other constraints are mainly environmental in substance, and concern inappropriate means of disposing of organic wastes. Examples are on-land applications of untreated wastes, which may contain pathogens, toxic organic chemicals and harmful volumes of heavy metals; excessive on-land applications leading to surface or ground water contamination and/or odor pollution; continuous on-land applications leading to nutrient imbalances in both soil and plants.

The objective of this paper is to examine the economics of composting and alternative ways of handling organic wastes, having due consideration for any environmental constraints.

A Comparison of Organic Waste Disposal Alternatives

Organic wastes from the urban-industrial complex, including sewage, were traditionally disposed of on agricultural land throughout the Western world until the closing stages of the nineteenth century (de Haan, 1981). This process of recycling plant nutrients and soil organic matter was disrupted by the introduction of cheaper, more convenient sources of plant nutrients in the form of inorganic chemical fertilizers, and by the advent of water closets and other technologically-based conveniences that favoured alternative disposal methods. It became fashionable to dispose of solid wastes in land-fill sites, while liquid wastes, including sewage, were frequently channelled into water bodies. Population growth and industrial development have more recently begun to restrict the opportunities for land-fill disposal in Canada, while concerns about environmental pollution have rendered water-course disposal operations less acceptable.

As a result, only about 25 percent of the 1.5 million m^3 of sewage annually produced in Ontario is de-watered and disposed of in land-fill sites, while approximately 40 percent is incinerated (for example, Toronto, London and Hamilton), 2 percent is composted (Windsor and Downsview, Toronto) and the remaining 33 percent is spread on agricultural or recreational lands (Bates, 1984; Ont. Min. Envir., 1984).

The portion disposed of on agricultural land is typically passed through primary and secondary treatment plants that permit filtration and bacteriological breakdown, and, in some municipalities, through tertiary treatment plants for reduction of phosphorus content. Problems nevertheless remain with on-land applications of sewage sludge, wherever industrial wastes containing toxic organic compounds and high concentrations of heavy metals are combined with sewage and municipal solid wastes. Repeated applications of contaminated wastes on agricultural land pose health problems through increased concentrations in plant material, and environmental hazards through heavier concentrations in the soil and groundwater (de Haan, 1984; Environment Canada, 1984). Such problems have led to the prohibition of on-land applications of contaminated wastes in Ontario (Bates, Lang and Bourque, 1983). Even where no environmental or health hazards are present, there may be economic problems associated with the on-land disposal option. Because of the low ratio of plant nutrients to

total bulk in sewage sludge (see Table 1) it is not economical to transport non-de-watered sludge for more than, say, 35 kilometres. On the other hand, de-watering entails high capital and operating costs. For example, for a de-watering plant with a daily capacity of 26 tonnes of thickened sludge (4% solids), combined operating costs and amortized capital costs were estimated by one source to be about $45.00 per tonne, dry matter basis (Metcalf & Eddy, 1983).

Land-fill disposal is becoming a less frequently used alternative, because of increasing unavailability of suitable land and because of rising land costs, especially in the vicinity of urban centres in southern Ontario. This alternative is furthermore wasteful of potentially usable resources in an era of rising resource extraction and development costs, and may be the cause of heavy metal and toxic organics contamination of groundwater on some sites. In addition, it is generally necessary to de-water the sewage portion of urban-industrial wastes prior to land-fill disposal. Against all these factors are the advantages of ease, convenience and cheapness relative to most alternatives, where suitable land is readily available.

Incineration of solid and liquid organic wastes offers the ultimate solution to disposal problems by leaving only very small non-combustible ash residues. It also produces a usable source of energy for heating, lighting or power, in the ratio of approximately 3 tonnes of steam to each tonne of dry matter organic waste input. However, like the land-fill option, it is wasteful of potentially usable plant nutrient and organic matter resources. At this juncture, it is a debatable point as to whether the need for organic matter to replenish soil humus stocks and to maintain agricultural productivity is greater than the need for energy for heat, light and power on a worldwide basis. In addition it is the most expensive facility to construct and by far the most expensive to operate (see Table 2), it may need relatively scarce fossil fuel energy resources to help it to function, and it may create air pollution difficulties in place of groundwater pollution problems.

The composting alternative enjoys the advantages, along with on-land applications, of providing a means of recycling plant nutrients and organic matter to effect soil structure improvements. The compost is easily produced with low energy inputs, the storage period can be readily extended to ensure

Table 1: Composition of "Typical" Sewage Sludge, Municipal Waste Compost and Livestock Manure[a]

	Sewage Sludge	Municipal Waste Compost	Livestock Manure
Solids (%)	3.5[b]	58	17
		(% in dry matter)	
Total Kjeldahl Nitrogen	4.0	2.1	4.5
Phosphorus	2.4	2.5	2.2
Potassium	0.5	0.33	2.5
Calcium	4.4	5.0	1.9
Magnesium	0.75	0.6	0.8
Sodium	0.02	0.4	0.45
Chlorine	0.7	0.4	0.9

[a] Actual composition of these organic waste products varies over a wide range

[b] Solids content of "thickened" sewage sludge is about 5%, and of "de-watered" sewage sludge, from 10% to 30%

Sources: de Haan (1981)
Environment Canada (1984).

Table 2: Costs of Processing Organic Wastes

	Surface Land Application	Land-Fill[a]	Compost[b]	Incineration[b]
		($ per tonne raw material)		
Sewage/Municipal Solid Wastes	12.00 - 20.00[c]	25.00 - 40.00	30.00 - 170.00	150.00 - 190.00
Livestock Manure	5.00 - 18.00	Ø	20.00 - 30.00	Ø
		($ per tonne dry matter)		
Sewage/Municipal Solid Wastes	240.00 -400.00[c]	50.00 - 80.00	52.00 - 300.00	250.00 - 320.00
Livestock Manure	140.00 -520.00	Ø	35.00 - 52.00	Ø

[a] Includes cost of de-watering sewage sludge

[b] Does not include cost of land

[c] Land application of sewage only

Sources: Fairfield Service Co., Marion, Ohio
Metcalf & Eddy, New York
Resource Recovery Systems, Windsor, Ontario
Ontario Ministry of Environment, Toronto, Ontario
Hill View Farms, Woodstock, Ontario
Roslyn Park Farms, New Dundee, Ontario
Kelland and Stonehouse (1984)

destruction of pathogens, and, for on-land applications, conventional manure-handling equipment can be used. Compared with on-land disposal options, composting is an expensive alternative. However, it compares very favourably with incineration, and is similar in costs to land-fill disposal options (see Table 2). The only potential environmental problems with compost occur either when industrial wastes containing contaminants are included in the raw material to be composted, or when compost is applied to land in excessive quantities, and during the actual composting procedure (with respect to odour pollution).

A summary of the principal advantages and disadvantages of organic waste disposal alternatives is contained in Table 3. From the viewpoint of disposal costs alone, surface land applications appear to be most heavily favoured. There are also resource recycling and environmental pollution considerations, and these may favour composting or incineration respectively. One further factor is the economic value to be placed on the organic waste for each disposal alternative, a value that can partially or entirely offset the processing and disposal costs.

Potential vs Actual Economic Benefits from Organic Wastes

One of the four disposal alternatives discussed above bears no potential economic benefits, namely land-filling. For application to agricultural land, livestock manures and sewage sludges should theoretically be worth their opportunity cost (i.e. the inherent value of plant nutrients that they are replacing from chemical fertilizer services) plus the value of improving soil structure and productivity, as reflected in long-term crop yield increases. Recent (1983) chemical fertilizer prices suggest that, according to the opportunity cost principle, land application of organic wastes should be worth $6.00 to $9.00 per tonne based on immediately available plant nutrients, but should be worth $16.00 to $20.00 per tonne based on total continually available plant nutrients (Environment Canada, 1984). To this should be added the value of increased crop yields in the long term (> 5 years) due to improved soil structure, of from $1.00 to $6.00 per tonne depending on the crop to which the organic waste is applied, and using a 4-percent rule-of-thumb factor for long-term yield increases (J.W. Ketcheson, 1983). The fact that farmers are apparently willing to pay only about $5.00 per tonne for general field crops, and only about $15.00 per tonne for more intensive crops like grapes

Table 3: Summary Comparison of Organic Waste Disposal Alternatives

	Advantages	Disadvantages
Surface Land Application	Recycles usable fraction of wastes No land costs Low capital and operating costs	Potential pathogen, heavy metal and organic toxic problems Need to store over winter Expensive to transport over long distances
Land-filling	Relatively inexpensive and convenient where suitable land available	Potential heavy metal and organic toxic problems Usable fraction of wastes lost Need to de-water sewage
Composting	Recycles usable fraction of water Simple process technically Storable commodity with pathogen destruction potential	Potential heavy metal and organic toxic problems Relatively expensive and requires land (processing and storage)
Incineration	Source of energy Complete elimation of pathogen, heavy metal and organic toxic problems	Usable fraction of wastes lost May use fossil fuel energy resources High capital and operating costs

and tobacco suggests that it is mainly the immediate benefits that are being assessed (and paid for).

Analogously, the inherent energy value from incineration, using the opportunity costs of alternative fossil fuel energy sources, would be approximately $5.00 per tonne of organic waste. It should be noted that values of energy would have to rise significantly in commercial markets before costs of incinerating organic wastes would be covered (see Table 2).

A similar analysis can be applied to the composting disposal alternative. A survey by Southgate (1984) of potential markets in Ohio suggested that horticulturalists ought to be willing to pay about $60.00 (Cdn) per tonne for composted sludge used as a potting/rooting medium; landscapers ought to be willing to pay up to $35.00 (Cdn) per tonne as a source of topsoil; land reclamationists should be willing to pay about $10.00 per tonne, and farmers about $4.00 per tonne. All of Southgate's value estimates were based on the opportunity cost of composted sludge in replacing alternative potting media, topsoil materials and/or fertilizer sources of plant nutrients. A survey of some of the few farmers composting manure and municipalities composting sewage and solid wastes in Ontario revealed that actual market prices being paid for compost in most cases met the opportunity cost levels according to the Southgate study. The exceptions were in some cases below, and in other cases above the opportunity cost levels, as indicated in Table 4. Test plot experiments at Ridgetown College of Agricultural Technology, Ontario, have indicated that compost from both the Downsview and Windsor municipal composting plants has a positive effect on grain corn yields, at least in the short term (Baldwin and Nuttall, 1983). Further experiments to determine the longer term effects of compost of different maturities and composition on soils and longer-term yields are in process of being reported upon.

Conclusions and Recommendations

From the above analyses of economic, resource use and environmental aspects of four organic waste disposal alternatives, the following conclusions are drawn:

1. Both surface land applications and composting represent superior alternatives from the points of view of recycling resources and overall net economic benefits.

Table 4: Potential[a] and Actual Market Values of Organic Wastes

	($ per tonne)
1) Surface Land Applications	
Potential Values[b]	
- immediately available plant nutrients	6.00 - 9.00
- eventually available plant nutrients	16.00 - 20.00
- including long-term soil improvements	17.00 - 26.00
Actual Values	5.00 - 15.00
2) Compost	
Potential Values[d]	
- potting/rooting medium	60.00
- topsoil for landscaping	35.00
- topsoil/conditioner for land reclamation	10.00
- agricultural/forestry lands	4.00
Actual Values[c]	
- potting/rooting medium (bagged)	85.00
- landscaping and bulk to garden centres, nurseries	11.00 - 40.00
3) Incineration	
Potential Values[e]	
- energy for power, light & heat	4.00 - 6.00

[a] Based on opportunity cost principle

[b] Source: Environment Canada (1984)

[c] Sources: Roslyn Park Farms, New Dundee, Ontario
Hill View Farms, Woodstock, Ontario
Resource Recovery Systems, Windsor, Ontario
Ontario Ministry of Environment, Toronto, Ontario

[d] Source: D.D. Southgate (1984)

[e] Source: L. Otten, Sch. of Engineering, U. of Guelph, personal communication.

2. Both land-fill and incineration alternatives pose the smallest potential environmental pollution hazard, and represent the only sensible alternatives in cases where industrial wastes containing heavy metals, toxic organics and other contaminants are mixed with sewage and solid municipal wastes, resulting in heavily contaminated mixtures.
3. Even where sewage and solid municipal wastes are low in or void of contaminants, they and livestock manures must be applied on land with care to avoid surface or ground water pollution problems.

Based on the above conclusions, it is recommended that:

1. Ontario farms and municipalities consider on-land or composting methods of organic waste disposal in future, whenever present capital facilities for incineration require renewal or whenever land-fill disposal sites become exhausted;
2. Ontario municipalities segregate contaminated industrial wastes from re-usable sewage and solid wastes in order to lessen environmental pollution hazards;
3. increased research efforts be invested into increasing and improving knowledge about the longer-term agronomic and economic benefits of on-land waste disposal and composting, and the comparative costs and environmental effects of organic waste disposal alternatives.

References

Baldwin, C.S. and M. Nuttall 1983. "Compost Research 1982", Ridgetown College of Agricultural Technology, Ridgetown, Ontario.

Bates, T.E. 1984. Dept. of Land Res. Sci., University of Guelph, Ontario, personal communication.

Bates, T.E., H.C. Land and J.L. Bourque 1983. "How and Where to Use Sewage Sludge in Crop Production." Ont. Min. Agric. & Food, Fact Sheet, Agdex 100/541.

Becktell, R. 1984. Roslyn Park Farms, New Dundee, Ontario, personal communication.

Coulson, M. 1984. Resource Recovery Systems, Windsor, Ontario, personal communication.

de Haan, S. 1981. "Results of Municipal Waste Compost Research over more than fifty years at the Institute for Soil Fertility, Haren/Groningen, the Netherlands." Neth. J. Agric. Sci. 29:49-61.

Environment Canada, 1984. Manual for Land Application of Treated Municipal Wastewater and Sludge. EPS 6-EP-84-1, Ottawa, Ontario.

Fairfield Service Co. 1984. "Fairfield Resource Recovery Process." Marion, Ohio.

Kelland, D. and D.P. Stonehouse, 1984. A Mixed Integer Programming Model for Analyzing Manure-Handling Systems Alternatives. School of Agric. Economics & Ext. Education, University of Guelph, Ontario.

Ketcheson, J.W. 1983. Dept. Land Res. Sci., University of Guelph, Ontario, personal communication.

Metcalf and Eddy of New York, Inc. 1983. The Clinton County Compost Project. New York, New York.

Provias, P. 1984. Ontario Min. Environment. Downsview Recycling Plant, Toronto, Ontario, personal communication.

Schell, Paul, 1984. Hill View Farms, Woodstock, Ontario, personal communication.

Southgate, D.D. 1984. "Potential Markets for Akron Sludge-Derived Compost." Ohio Report Research and Development in Agriculture, Home Economics and Natural Resources. 69(3):40-41.

CASE STUDY

DELAWARE RECLAMATION PROJECT

BY

J. S. COULSON

FAIRFIELD SERVICE COMPANY

MARION, OHIO

The Delaware Reclamation Project (DRP) is owned by the Delaware Solid Waste Authority (DSWA) which was created in 1975 by the Delaware General Assembly as an independent Authority of the State of Delaware for the purpose of planning and implementing a long range program for solid waste disposal.

Construction of the DRP was completed in 1983 near Wilmington in New Castle County and serves a population of approximately 400,000. The DRP operates two 8-hour shifts per day and 5 days per week. The facility is designed to process 1000 TPD of municipal solid waste and 350 TPD of 20% solids sewage sludge from the 90 MGD Wilmington Regional Wastewater Treatment Plant. The DRP consists of a Solid Waste Processing Module (SWPM) and Sewage Sludge Processing Module (SSPM). Construction of a third module, Energy Generating Facility (EGF), is scheduled to commence soon. The EGF will generate 13 megawatts (mW) of electricity by utilizing refuse derived fuel (RDF) produced in the SWPM. About 5.5 mW of the electricity will be used by the DRP and the remainder sold to the local utility.

The Humus Processing System (HPS) of the SSPM is designed to co-compost a mixture of approximately 350 TPD each of air classified shredded solid waste and sewage sludge.

The Raytheon Service Company has the operating responsibility for the complete DRP and, as subcontractor, Fairfield operates the HPS.

The SWPM consists of a tipping building where trucks dump the solid waste on the floor and front-end loaders move the refuse into two lines of receiving hoppers, steel belt conveyors and shredders. Each line has sufficient capacity so that one line is stand-by. A separate building houses the rotary drum air classifiers that removes approximately 500 TPD of the light fraction consisting mostly of paper and plastic film as RDF. The RDF is currently being landfilled until the EGF is operational. The heavy fraction discharged from the air classifiers is conveyed through a magnetic separation system where ferrous metal is recovered and marketed. The solid waste is then introduced into a rotary trommel screen where glass rich fines are separated from the remainder of the solid waste which is conveyed as one infeed material to the HPS. The glass is recovered and marketed from the fines by using a wet process. The residue, after glass separation, is dewatered with a high organic content sludge which is conveyed as another infeed material to the HPS. The sewage sludge infeed is trucked to the DRP from the wastewater treatment plant, after having been dewatered to 20% solids, and dumped into three enclosed receiving hoppers, having holding capacity of approximately 15 tons each, with screw type adjustable speed unloaders.

The solid waste conveyed to the HPS can alternately be stored in a 50 ton capacity surge bin having an adjustable speed unloader or, by means of conveyors, by-pass the bin and discharge into a rotary air classifier where the heavy non-ferrous fraction is removed and conveyed to the non-ferrous recovery system which is located in the HPS building. The non-ferrous metals, mostly aluminum, is marketed. The residue from the non-ferrous separator is introduced into an air-knife classifier that removes heavy non-compostable materials such as wood, hard plastics and building rubble for transport to a landfill. The light fraction from the rotary and air-knife classifiers is conveyed to a cage mill. The organic sludge from the glass recovery system and the sewage sludge are also conveyed to the cage mill. The mill consists of multiple cages that rotate in opposite direction and perform the final size reduction of the solid waste and pulp the three infeeds into a homogeneous material containing approximately 50 to 60 percent moisture before being introduced into four Fairfield Digesters.

The Fairfield Digester is a continuous flow automatically controlled aerobic-thermophilic bio-reactor. Each of the four Fairfield Digesters are 100'-0" in diameter with approximately 10'-0" high reinforced concrete wall, floor and tunnel.

Material is fed into only one digester at a given time. The infeed material enters each digester at the top center and is discharged adjacent to the circular shaped wall by means of a belt conveyor mounted on a structural steel bridge. Twenty-three (23) aerator screws, supported from the bridge structure, aerate and move the material from the digester wall to the center discharge weir in 5 to 7 days. The supporting bridge structure rotates 360-degrees around the digester wall by means of variable speed motor driven wheels traveling on a T-rail track mounted on top of the concrete wall. The bridge normally completes one 360-degree travel within approximately two hours.

Each of the aerator screws is furnished with a variable speed motor drive assembly. The aerator screws and bridge assembly operates only when material is being introduced into the digester or material is being discharged from the digester. In addition to aerating the material and moving it through the digester, the aerator screws also reduce the particle size thereby exposing more surface area to oxidation for efficient biological processing of the organic matter. Circular shaped PVC air pipes are embedded in stone in the bottom of each digester in five separate aeration zones. Automatically retractable combination temperature and oxygen sensor probes are provided for each zone and motor operated valves are interlocked with preset temperature and oxygen controls to automatically maintain 140 to 160 degree F. temperature and 12 to 16 percent interstitial oxygen within the aeration zones. The air blower system operates 24 hours each day.

Each digester is totally enclosed by an aluminum dome covering the top of the concrete vessel.

Compost discharged from the digesters contains approximately 50% moisture and is conveyed to a vibrating screen where oversize residue such as rags, wood, plastics, etc. are removed and transported to the landfill. The prime sized compost is conveyed from the screen to an outdoor storage area. A front-end loader is utilized to transport the compost from the yard storage area to a receiving hopper and feeder. The compost is conveyed from the receiving hopper to a triple pass rotary dryer that dries the compost from about 50% moisture at the infeed to 15% moisture at discharge. The dryer is provided with a dust collector and solid waste burner that utilizes combustible residue from the HPS as fuel and with a back-up fuel oil burner. The dried compost is screened to remove plus 3/8 inch oversize material which becomes part of the fuel for the dryer. The 3/8 inch and under compost is conveyed to two stoner-classifiers where dense inorganics such as stones, glass, grit, etc. are removed and the prime product is conveyed to two storage bins as unpelletized humus product. The bottom of each bin is provided with an unloader to fill trucks. Approximately 50% of the compost produced at the DRP is marketed as unpelletized humus bedding litter for poultry houses located in the Delmarva Peninsula.

Alternately, the unpelletized humus can be pelletized, further dried from about 15% moisture to 10% moisture by an oil-fired gravity tower dryer, granulated and screened to a 7 to 20 mesh pelletized humus product that is sold to the horticultural market. The undersize humus discharged from the screen is conveyed to the solid waste burner and used as fuel. The pelletized humus is free-flowing and stored in four bins. A conveyor system from the storage bins can alternately load trucks or railroad cars.

All DRP humus products are marketed in bulk shipments. The unpelletized humus is sold directly by Fairfield. The pelletized humus is marketed by a distributor having sales coverage in the five state area around the plant.

UNIVERSITY OF GUELPH AND ROSLYN PARK FARM COMPOSTING SYSTEM

by: J. Pos,
University of Guelph

INTRODUCTION

The current composting research program at the University of Guelph was initiated in 1969 when a pilot plant was designed and constructed for high-rate aerobic decomposition of poultry manure[1]. A larger unit using a chain-and-flight conveyor for mechanical agitation was built the following year for 'Winter High Rate Composting of Broiler Manure'[2]. The pilot plant was re-built in 1972 to include a 25 horsepower hammer mill, a one ton ribbon mixer and mechanical conveyors for automatic transport of raw materials. The modified facility was used for 'High Rate Composting of Municipal Refuse and Poultry Manure'[3]. During the next 5 years the facility was used to compost a variety of materials including: hardwood and softwood bark, wood waste from saw mills, clarifier screenings from the pulp and paper industry, harvested aquatic plants,[4,5,6,7,8] pressed cedar trimmings from a Toronto firm producing herbal shampoo, paunch manure from a meat packing plant and livestock manures. A technical report #126-37 titled "Composting" (9) was published in 1977.

ROSLYN PARK FARM

This is primarily a beef cattle, contract feed lot system. In 1977, the operation accommodated about 4,500 animals providing a turnover of 18,000 animals per year. With a limited land base, and to avoid surface runoff and groundwater pollution, it was necessary to separate the manure slurry into solid and liquid fractions with the liquids being irrigated on the land which was used predominately to grow corn, and the solid fraction to be sold off the farm. To enhance the quality of the solid fraction, reduce the odours and increase the profit potential, it was apparent that some type of composting should be investigated.

The modified pilot plant with the chain and slat, agitation conveyor was used for the preliminary trials to compost the separated solids having a moisture content ranging from 60 to 70%. The results were most encouraging and a commercial scale composting system was subsequently designed by "Jack Pos and Associates" and built and installed by the owner. In the meantime the feedlot had been expanded to accommodate 5,400 animals.

DESIGN OF HIGH-RATE COMPOSTER

Container

The selected site included an abandoned single storey turkey barn of pole construction and a dirt floor. The building dimensions were 76 m (250') x 17 m (56') with the parallel center poles 7.3 m (24') apart. The preliminary investigations had shown that a 7-9 day retention time with mechanical aeration and protection from the elements resulted in a stable end product. Therefore, by introducing the raw materials at each end of the building and allowing a daily displacement of 3 m (10'), a retention time of 10 days was achieved. This provided a safety factor of 1 to 2 days for unscheduled down

time. Two parallel support walls, 122 cm (48") in height, of wood and plywood construction the full length of the building provided containment for the composting mass.

Mechanical Agitator - Mixer

The 7.3 m (24') clear span would have created a massive weight problem if the chain-and-flight conveyor system had been used for agitation and daily transport. It was therefore decided to use the flail-chain concept, which had proven to be successful in bottom unloading of silage from tower silos. To avoid excessive deflection, the horizontal flail shaft was cut in two and supported in the center with pillow block bearings. This made it possible to mount the motor and chain drive assembly at each end and directly over the support wheels. The 900 mm (36") long chain with cutting heads were welded to the main drive shaft on 225 mm (9") centers in a spiral configuration to provide a balanced load. To offset the lateral thrust, the pitch (spiral configuration) was pointed in opposite directions for the two co-axial shafts. With a rotating speed of approximately 550 rpm and a peripheral speed of 53 m/sec (10,000 ft/min.), the particle trajectory against a trailing curtain provided ample agitation and a mass transport of 3 m (10') per day.

Mechanical Agitator - Drive Mechanism

The mechanical agitator, measuring 7.3 m (24') x 4 m (14'), was supported by four 0.7 m (28") diameter steel flanged wheels on steel rails. The drive mechanism included a DC electric motor with variable speed control, 2:1 belt drive and a 60:1 single reduction gear reducer. The forward operating speed was 27 m/hr (1.5 fpm) and the high speed return was 270 m/hr (15 fpm). Electric power was transferred to the travelling agitator by means of buss bars mounted on the ceiling.

Mechanical Aeration

Aeration was provided by means of a 24 m^3/sec. (50,000 cfm) blower at 0.75 kPa (3" H_2O) static pressure. This was calculated on the basis of 0.05 m^3/sec, m^2 (10^{-3} ft^3/min, ft^2) of diffusion bed surface. A large air plenum, 1.5 m (5') wide x 1.5 m (5') deep and 8.5 m (28') long, of concrete construction was built across the center and under the composter. Parallel rows of 150 mm (6") PVC perforated plastic pipe 600 mm (24") O.C. provided air ducts from the air plenum. Crushed stone, to a depth of 100 mm (4") above the pipe surface provided the diffusion bed for air distribution. Aeration was provided at a frequency of 4 minutes every hour.

Product Transport

The finished product was removed from the center of the composter by means of an endless chain and flight conveyor (standard barn cleaner) and an inclined ramp for direct loading into a bulk transport vehicle.

Operation

Approximately 25 tonnes of separated feedlot manure was placed at each end of the composter daily By operating the mechanical mixer, first from the center to one end and back and then from the center to the other end and back, the composting mass was shifted 3 m (10') toward the center each day providing

about a 10 day retention time. With a 40% reduction in volume during the composting process, about 30 tonnes of finished compost are removed daily.

UNIVERSITY OF GUELPH COMPOSTER

In 1979, a Manure Management Committee was appointed by the Dean of the Agricultural College to look into the problems of manure handling on the campus and at various Research Stations operated by the University. On the campus, animal manures are produced at the hospital wards of the Veterinary College, and at the animal holding unit and main dairy barn of the Department of Animal and Poultry Science. The waste from the hospital wards is predominately long straw with some animal manure having an average density of 112 kg/m^3 (7 lb/ft^3). About 2.0 metric tonnes are produced daily. This was being collected by a solid waste packer truck and disposed at a land-fill site under contract. The consolidated density was about 250 kg/m^3 (15.6 lb/ft^3).

Animal manure from the main dairy barn was diluted with wood shavings and collected by means of a mechanical gutter scraper and stock piled in a shed. The material was then transported weekly to a field stack and disposed on the land in the spring. The density of the material, as collected in the barn, was about 256 kg/m^3 (16 lb/ft^3) and the average daily production was about 2.5 metric tonnes.

The Manure Management Committee recommended that the manure produced at both of the above locations be combined and composted at a central location and the finished product to be used by the grounds department.

DESIGN OF UNIVERSITY COMPOSTER

Even with space limitations, it was decided to construct the unit immediately adjacent to the main dairy barn since the raw materials could be scrapped directly into the loading end of the proposed composting unit. The basic design was much the same as that used for the Roslyn Park Farm composter, although a more permanent structure with concrete walls was used to enclose the operation.

Mechanical Agitator - Mixer

The initial design used the flail-chain concept, but after the first 6 months of operation, which included some experimentation, the chains were replaced with a linkage arm consisting of a 50 mm (2") diameter heavy wall pipe by 45 cm (18") in length welded at right angles to the main shaft; a swinging extension arm, which pivoted on two roller bearings, made from a flat steel plate 9 mm (.375") x 100 mm (4") x 500 mm (20") with a striking plate 250 mm (6") x 250 mm (6") x 12 mm (.5") welded to the outer end. These were placed 225 mm (9") on centers in a spiral configuration. The shaft, which rotated at a speed of 550 rpm, was driven by a roller chain and gear drive coupled to a 25 horsepower electric motor.

Mechanical Agitator - Drive Mechanism

The mechanical agitator is 4.5 m (15') square and is supported at each of the four corners by a 300 mm (12') diameter steel flanged wheel on steel

rails. The drive mechanism includes a 0.75 horsepower electric motor at 1140 rpm with a reversing switch and a variable sheave belt drive with a 1.2 - 1.7/1 ratio; a 4 speed transmission with gear ratios ranging from 6.5/1 to 1/1 and a belt drive with a ratio of 3.2/1; a gear reducer with a reduction of 60/1; the torque drive from the gear reducer is connected to a pull chain sprocket with a 2.5/1 chain drive. The pull chain sprocket has a 559 mm (22") travel per revolution. The present drive train is providing a forward travel speed of 170 mm (6.7") per minute in 1st gear and a return speed of 1100 mm (43") per minutes in 4th gear.

Mechanical Aeration

Mechanical aeration was provided by a blower rated at 7 m^3/sec (14,000 cfm) at 0.75 kPa (3" H_2O) static pressure. The crushed stone diffusion bed was of similar construction to that for the Roslyn Park Farm composter. The blower is operated on a timer control which provides 4 minutes of aeration every hour.

Product Transport

Composted material was removed at the end of the process by means of an endless chain and flight conveyor installed below the level of the composting bed with an inclined extension for direct loading into bulk transport or temporary stock piling.

Operation

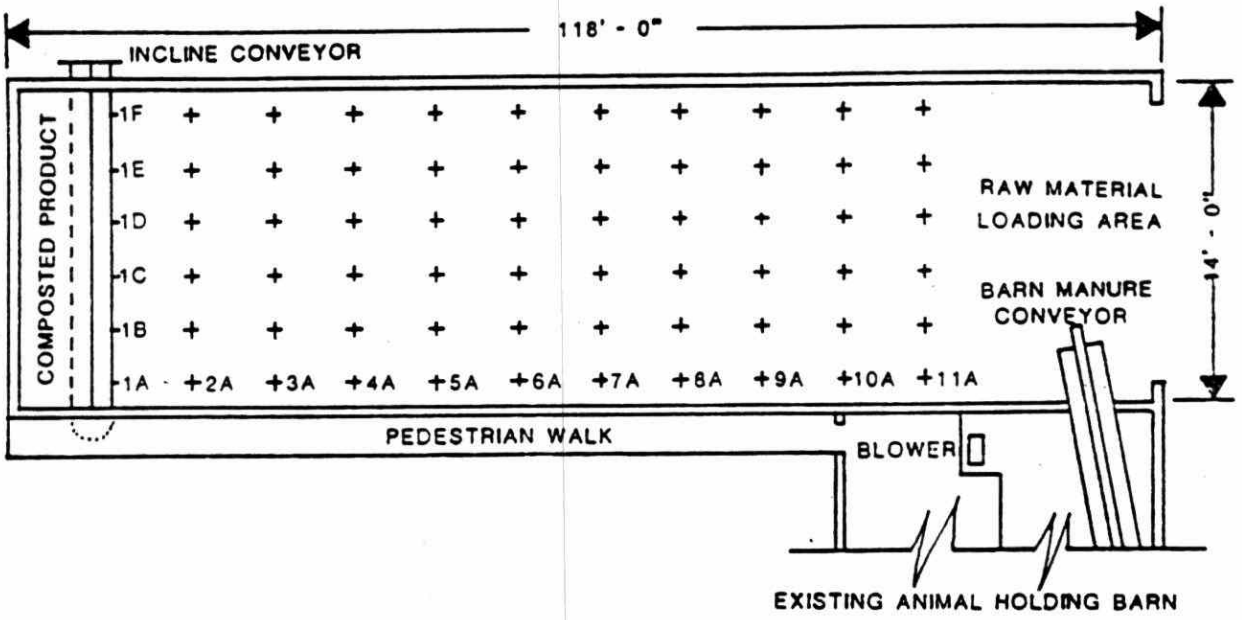
Raw material from the hospital wards and the main dairy barn is mixed together and distributed at the input end with a front-end loader. An overhead sprinkler with two spray nozzles that give a uniform distribution across the width of the composter is used to increase the moisture content when necessary. Originally the mechanical agitator made a single pass each day resulting in a 10 day retention time. Currently, because of an increase in the volume of manure processed, it is operated 9 times per week resulting in a 7 day retention time and about a 35% reduction in mass. The end product (approx. 3 metric tonnes/day) is stable and of good quality.

RESULTS

Figure 1 gives a plan view of the University of Guelph Composter and identifies the sampling and temperature monitoring stations. Numerals from 1 to 11 give the longitudinal locations which are 2.5 m (8') apart; and the alphabet characters from A to F give the cross-sectional locations. By recording temperatures for at least three different levels at each of the 66 defined stations, no less than 198 temperatures can be plotted yielding a comprehensive temperature profile of the composting mass.

A comparison of composting temperatures at Station "11A" (near the raw materials input end of the composter) and the air temperature recorded by the University of Guelph Weather Bureau is shown in Figure 2. The temperature of the composting material was consistently 60 deg.C higher than the ambient temperature throughout the 10 week period without the application of any external heat. The dashed portions of the solid line graph for composter temperatures indicate the weekend periods from Friday afternoon to Monday

SAMPLING STATIONS - IDENTIFICATION CODE



PLAN VIEW OF UNIVERSITY OF GUELPH COMPOSTER

NUMERALS, 1 to 11 : Longitudinal axis.

ALPHABET, A to F : Cross-sectional axis.

DEPTH IN INCHES, : Vertical axis

Figure 1 : Schematic plan of the University of Guelph composter, showing the sampling stations and identification code

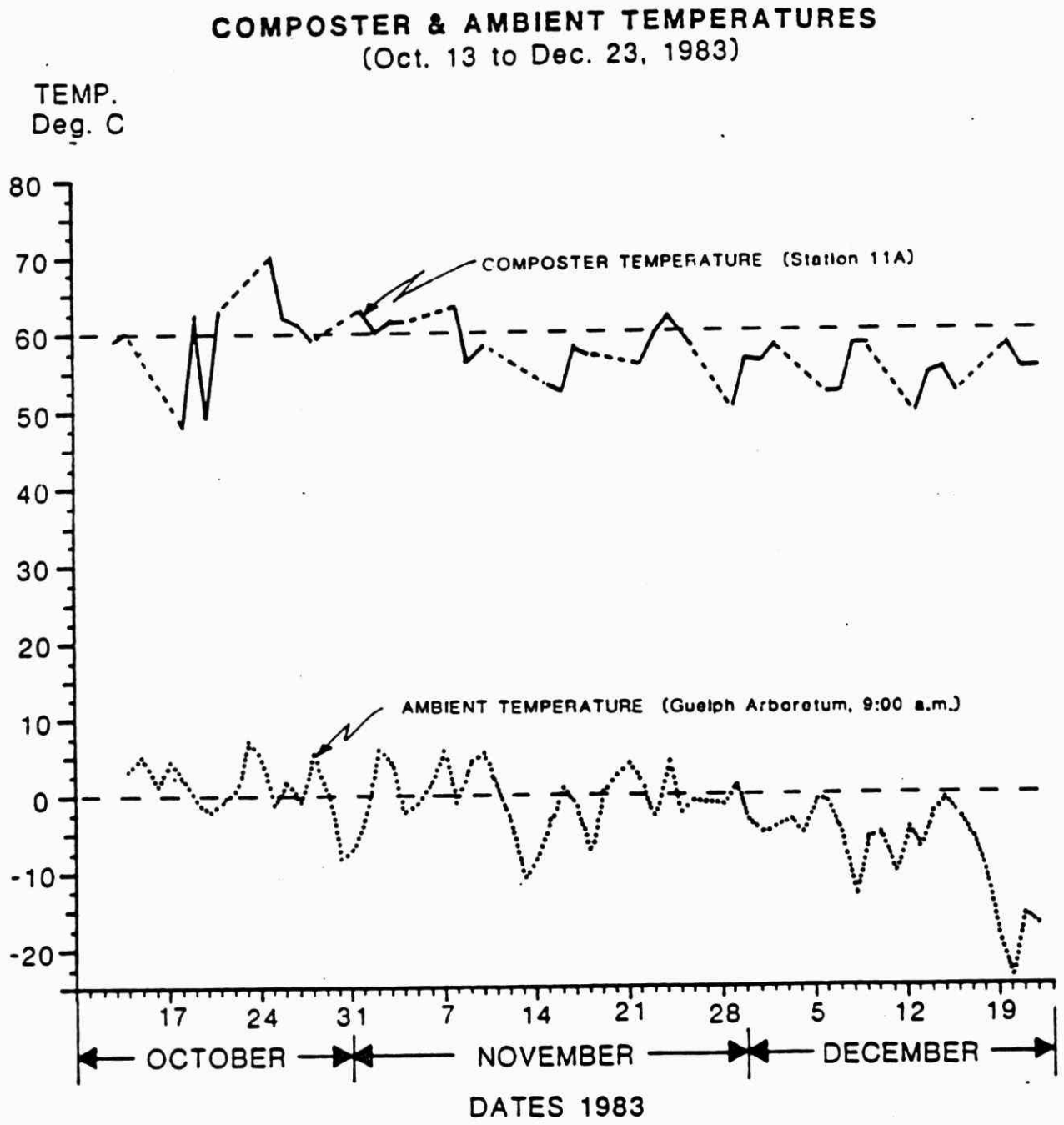


Figure 2 : Comparison of composting temperatures at Station "11A" and the air temperature recorded at the University Arboretum during the period October 13th to December 23rd, 1983.

morning when the composter was not in operation. In fact, without the daily agitation on the weekend, the temperature decreased approximately 15 deg.C, thereby demonstrating the necessity for consistent daily operation.

Representative samples were taken from the composting mass at various stages during the composting process. Material was removed at five equally spaced locations across the width of the composter. The aggregate total was thoroughly mixed and two replicate samples used for analysis. The average values are tabulated in Tables 1 to 4.

The analysis presented for the sample representing "Station 1", is the average of two replications and represents the final product after a 10 day retention time, while that for the sample from "Station 10" is representative of the raw material at the beginning of the process.

When reviewing the data from bottom to top (Station 10 to Station 2), as representing time lapse in the biological process commencing with the raw material at "Station 10" and finishing with the stabilized product at "Station 2", it must be remembered that there is an accumulating loss of total mass which will result in a net loss of 35 to 45 percent by weight. Therefore, while there is considerable moisture given off as vapour from the process, the percent moisture present at any time is relatively constant because of the actual reduction in dry matter. Because of the relatively high nitrogen content of the raw material as indicated by the low carbon to nitrogen ratio for the raw material, there is an apparent loss of ammonia by volatilization as shown for the finished product. However, on examining the figures for Organic N and Total N, it would appear that ammonia N is being converted to organic N thereby enhancing the quality of the finished product.

Figures 3 to 6 are further illustrations of the temperature profile along the longitudinal and cross-sectional axis of the composter. Essentially high temperatures are maintained across the width of the composter during the initial 100 hours and gradually decline to near ambient temperatures. Temperatures were also recorded for the temporary stock-pile after composting; since they were very close to ambient the finished product was assumed to be biologically stable.

Dry matter and ash content for the composting material as it progresses through the process is graphically illustrated for "Station C" in Figure 7. As one would expect, the ash content increases progressively as the organic material is decomposed.

TABLE I
(October 26, 1983)

Station No.	pH	NH_4 (ppm)	Org.N. (ppm)	Total N (%)	Dry Matter (%)	Volatile Solids (%)	C/N Ratio
2	—	-	5761	0.576	34.54	90.24	27.06
4	—	-	5040	0.504	32.33	91.39	25.77
6	—	126	4900	0.503	35.45	91.45	35.39
8	—	140	4690	0.483	30.65	92.07	36.51
10	—	1434	3500	0.492	24.36	90.63	48.22

TABLE II
(November 8, 1983)

Station No.	pH	NH_4 (ppm)	Org.N. (ppm)	Total N (%)	Dry Matter (%)	Volatile Solids (%)	C/N Ratio
2	8.5	280	5250	0.553	37.21	91.05	30.80
4	8.6	182	5040	0.522	33.61	89.66	28.84
6	8.7	308	3920	0.423	28.26	89.79	30.00
8	8.6	335	3444	0.383	27.65	92.32	33.33
10	8.1	2394	3710	0.610	26.54	89.01	19.50

TABLE III
(November 23, 1983)

Station No.	pH	NH_4 (ppm)	Org.N. (ppm)	Total N (%)	Dry Matter (%)	Volatile Solids (%)	C/N Ratio
2	—	119	4200	0.432	30.74	90.40	32.18
4	—	189	4200	0.439	29.73	90.97	30.83
6	—	413	4760	0.517	30.45	89.73	26.41
8	—	504	4480	0.498	33.47	92.13	34.40
10	—	734	5250	0.603	29.66	92.17	22.65

TABLE IV
(December 14, 1983)

Station No.	pH	NH_4 (ppm)	Org.N. (ppm)	Total N (%)	Dry Matter (%)	Volatile Solids (%)	C/N Ratio
2	—	455	4200	0.466	31.74	90.75	30.94
4	—	476	4410	0.489	29.75	90.41	27.52
6	—	616	5040	0.566	32.69	90.20	26.07
8	—	1739	4424	0.616	37.79	88.41	27.08
10	—	1897	5530	0.743	30.06	90.60	18.33

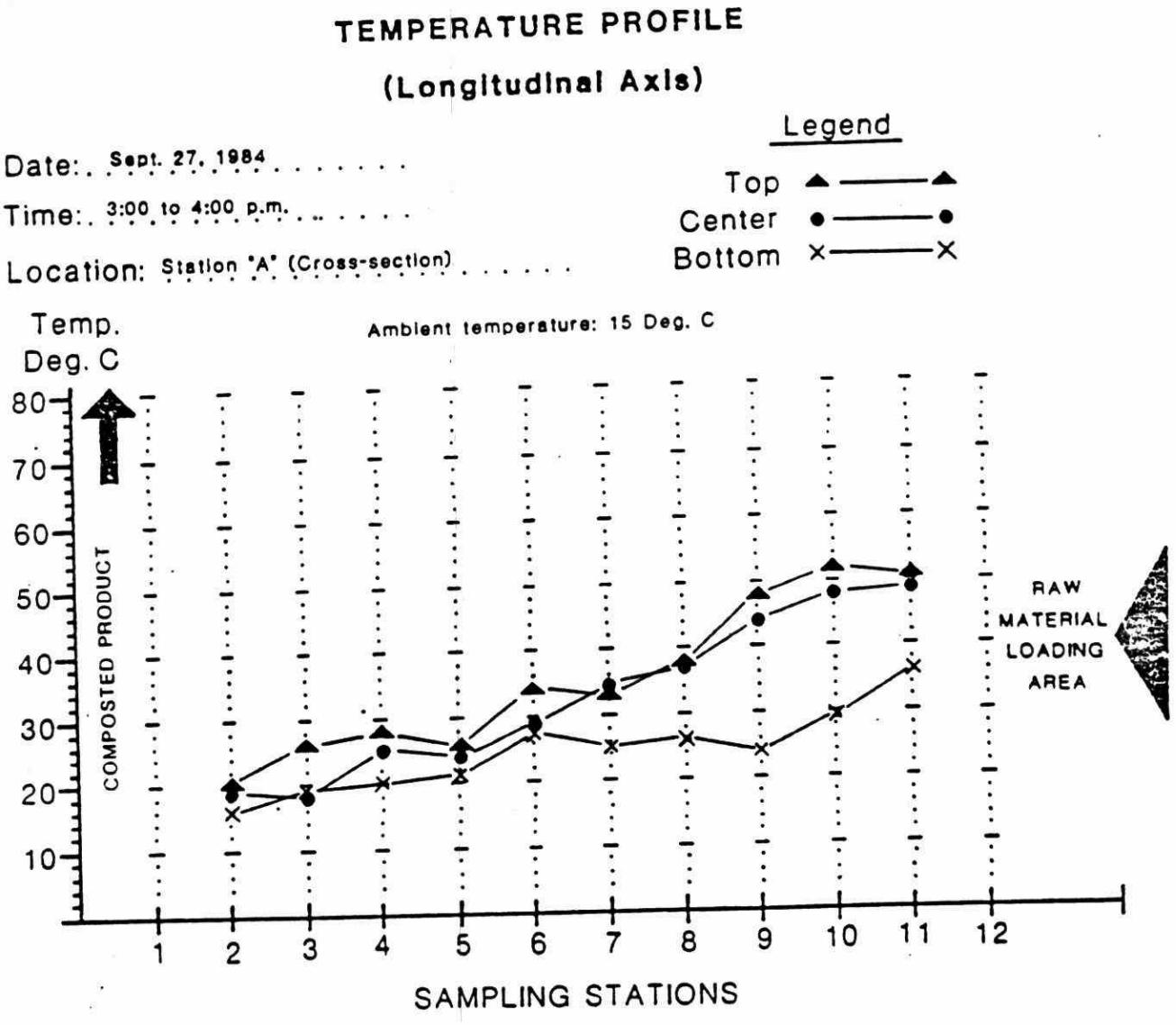


Figure 3 : Temperature profile along the longitudinal axis at "Station A" of the cross-section, September 27, 1984.

TEMPERATURE PROFILE
(Cross-section Axis)

Date: Sept. 27, 1984

Time: 3:00 to 4:00 p.m.

Location: Station "10"

Ambient Temperature: 15 Deg. C

Legend

Top: ▲ ——— ▲

Center: ● ——— ●

Bottom: × ——— ×

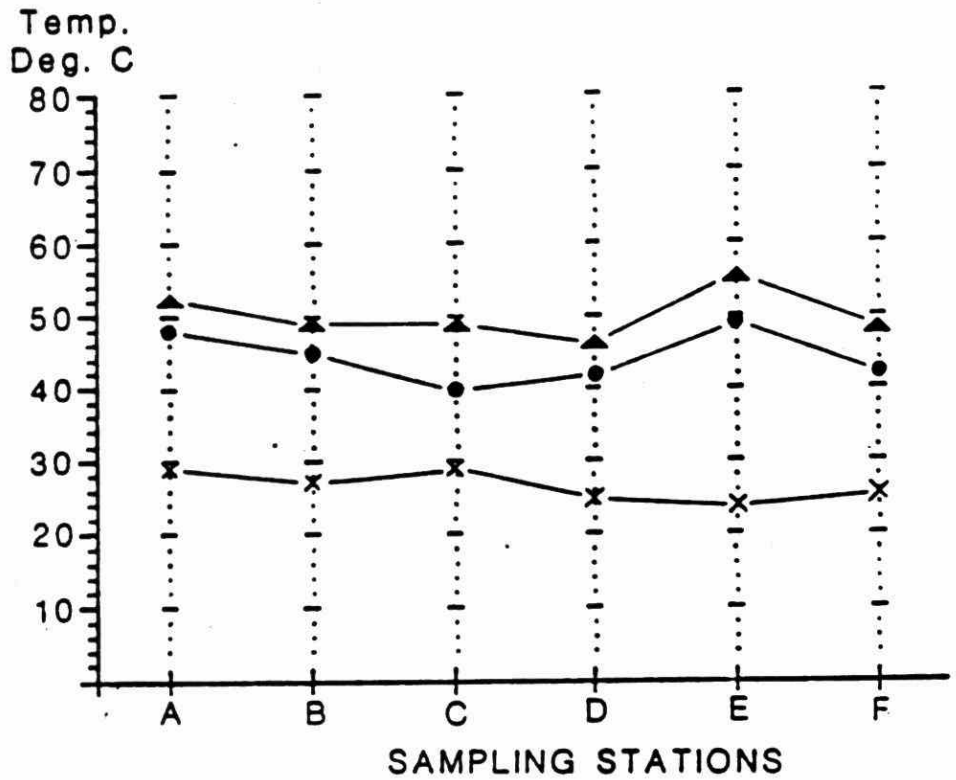


Figure 4 : Temperature profile along the cross-sectional axis at "Station 10", September 27, 1984.

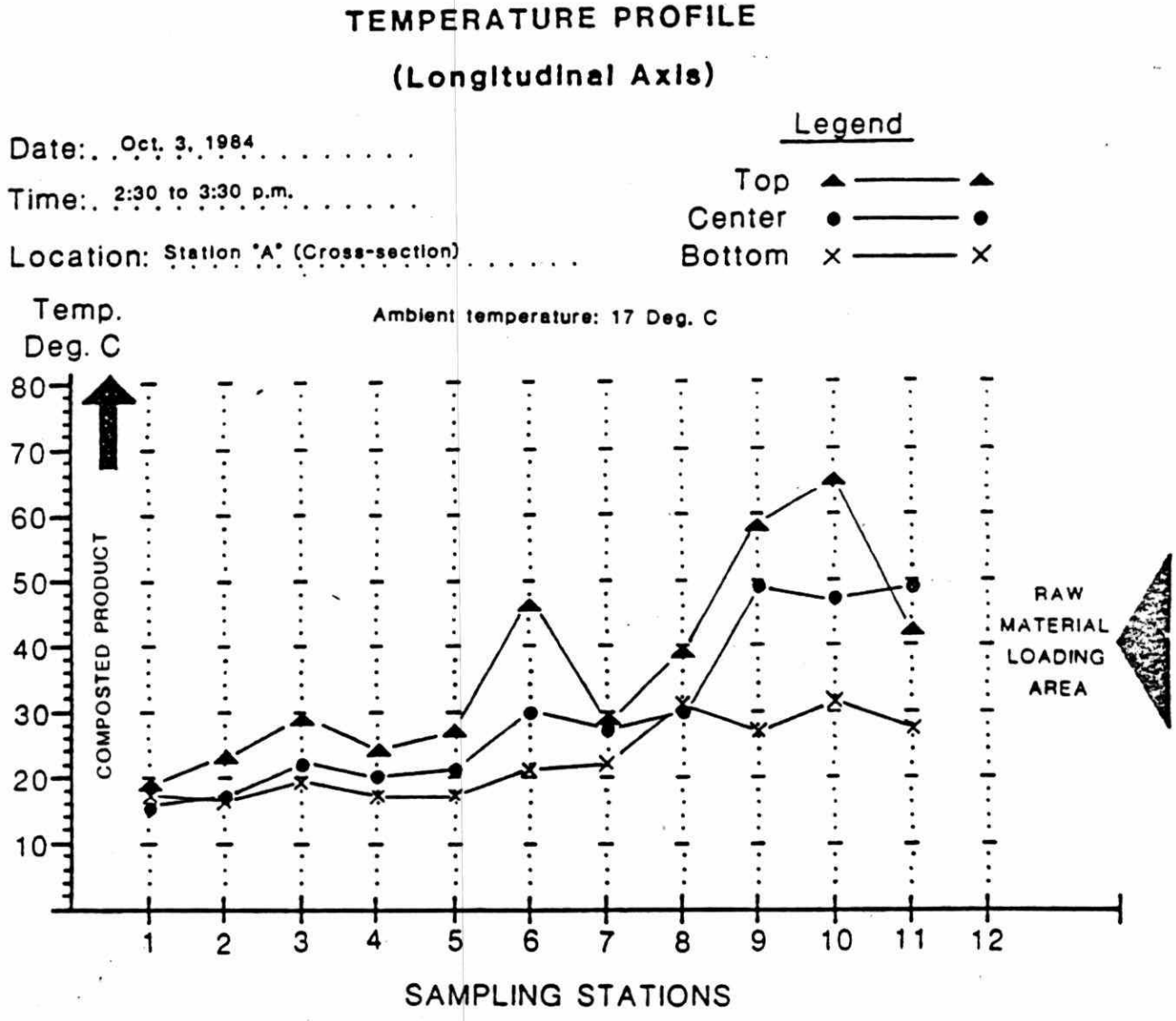


Figure 5 : Temperature profile along the longitudinal axis at "Station A" of the cross-section, October 3, 1984.

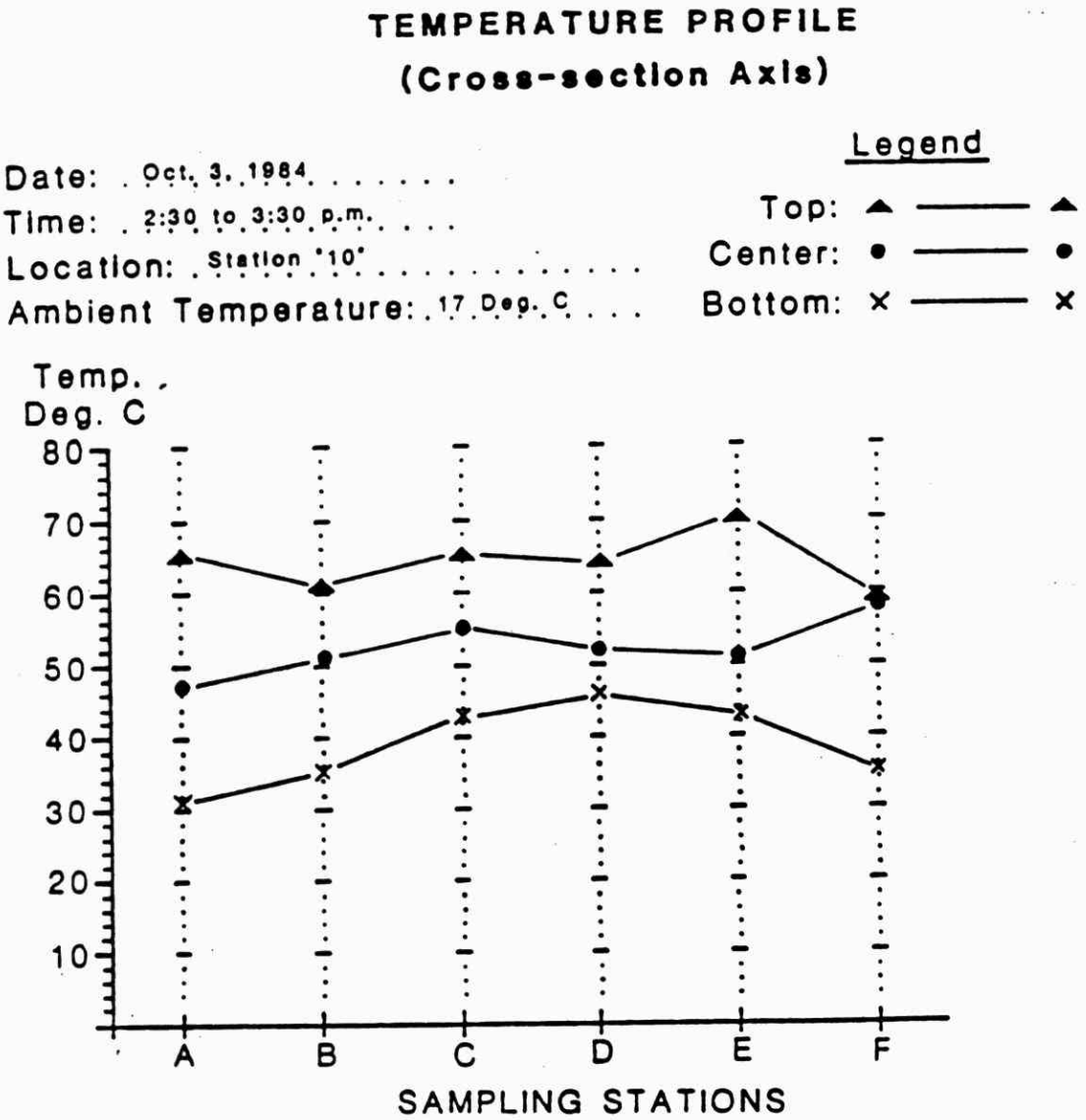


Figure 6 : Temperature profile along the cross-sectional axis at "Station 10", October 3, 1984.

DRY MATTER AND ASH CONTENT
(Longitudinal Axis)

Date: Oct. 11, 1984

Time: Afternoon

Location: Station "C" (Top surface)

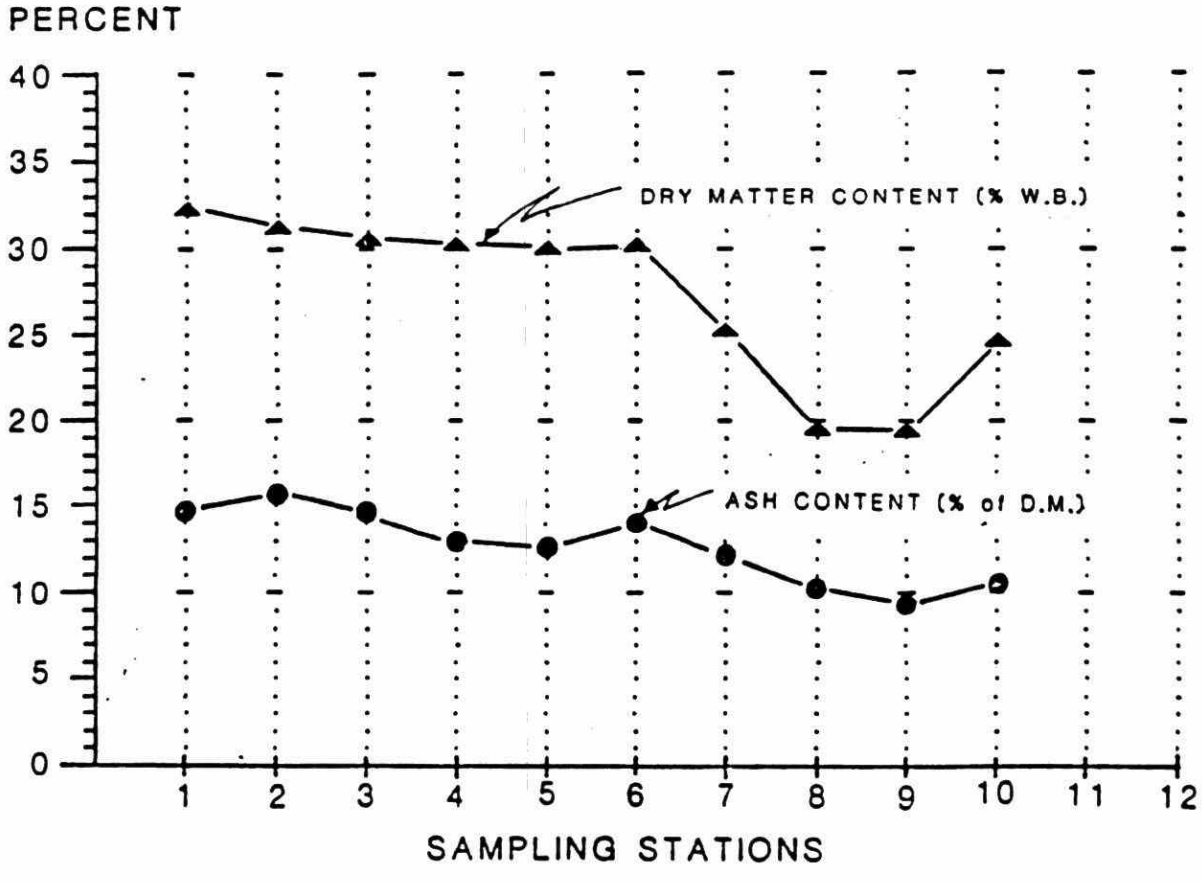


Figure 7 : Dry matter and ash content at "Station C" along the longitudinal axis.

REFERENCES

1. Bell, R.G., and J. Pos. Design and Operation of a Pilot Plant for Composting Poultry Manure, ASAE Transactions Vol.14, No.6:1020-1023. 1971.

2. Bell, R.G., and J. Pos. Winter High Rate Composting of Broiler Manure, Canadian Agr'l Eng., Vol.13, No.2:60-64. 1971.

3. Bell, R.G., and J. Pos. High Rate Composting of Municipal Refuse and Poultry Manure, Paper No. 72-210, presented at Annual Conference, Canadian Society of Agricultural Engineering, Charlottetown, P.E.I. 1972.

4. Bell, R.G., J. Pos, and R.J. Lyon. Production of Composts from Soft Wood Lumber Mill Wastes. Compost Science Vol.14, No.2:5-7. 1973.

5. Pos, J., and G.P. Lumis. Development and Evaluation of Wood Waste Compost. CPAR Project No.134, Phase 1, Canadian Forestry Service, Dept. of Environment. 1973.

6. Lumis, G.P., K.K. Wilson and J. Pos. Utilization of Wood-Waste Compost in Container-Grown Ornamentals. CPAR Project No.134, Phase 2, Canadian Forestry Service, Dept. of Environment. 1973.

7. Pos, J. Composting of Aquatic Plants. Part of the "Report of Studies on the Utilization of Harvested Aquatic Vegetation" submitted by Limnos Limited to the Ontario Ministry of the Environment dated March 21, 1975.

8. Holbrook, L., and J. Pos. Lets Compost More Refuse. Civic, Vol.29, No.1:34-36. 1977.

9. Pos, J. Composting. Technical Re[port No.126-37, School of Engineering, University of Guelph. 1977.

COMPOSTING SEWAGE SLUDGE
BY MEANS OF FORCED AERATION

AT THE

WEST WINDSOR POLLUTION CONTROL PLANT

by

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Department of Public Works

CANADA'S FIRST SYSTEM OF COMPOSTING SEWAGE SLUDGE BY MEANS OF FORCED AERATION

INTRODUCTION

This paper outlines how and why a composting process came about in the City of Windsor, Ontario. The experience obtained in Windsor possibly could assist other jurisdictions to evaluate the potential benefits of this method of sludge disposal.

Windsor operates two sewage treatment plants. The easterly Little River Pollution Control Plant is rated at 8 MGD and is conventional secondary. The West Windsor Pollution Control Plant has a present capacity of 35 MGD and uses physical-chemical technology.

The Little River Plant has for the past 12 years disposed of approximately one half of its sludge to a private free-enterprise composter. This sludge is extremely low in toxic heavy metals and the finished product is sold as a soil conditioner in Ontario and in the State of Michigan under the name "Grow Rich". The remainder of the sludge was disposed of at the City's sanitary landfill, along with sludge from the West Windsor Plant, until early 1973. In the summer of 1973, the sanitary landfill sites in the city were closed for disposal of refuse and sewage sludge and arrangements were made with a neighbouring municipality for the disposal of these wastes at a county landfill site some 25 miles away. Needless to say, the cost of disposal increased substantially.

The City's administration began looking for alternate ways of disposing of sewage sludge, such as a recycling program that might be economically feasible. We reviewed the composting process used by the commercial composter accepting the Little River sludge, however

this process used the windrow method and required extensive land and a sufficient buffer zone, which were not available to the City.

Heat treatment and incineration were evaluated, however the capital, operating costs were too prohibitive for the size of the City's two plants. It appeared as though continued landfilling would be the only solution. Then in 1976, the City Administrator was apprised of aerated rapid composting, as developed by the U.S. Department of Agriculture at its research laboratories in Beltsville, Md. Several field trips were made to Beltsville by City personnel to obtain first hand information on the process.

We decided to evaluate the composting process here in Windsor as to cost effectiveness and actual results obtainable from West Windsor sludge. (It must be remembered that sewage sludge has different characteristics which vary from plant to plant.) Experimental piles were built at the West Windsor Pollution Control Plant commencing in 1977, with the invaluable assistance of Dr. Eliot Epstein, Soils Scientist, who was retained as the City's composting consultant. Straw, corn cobs and woodchips were used as bulking agents and mixed with the sludge. The trials proved that the USDA aerated method of composting using woodchips worked very well in Windsor. Projected costs of composting were some 10 to 15 percent higher than haulage and burial at the landfill, however this did not take into account the value of the finished product, if indeed there was a firm market for compost. Also, the capital cost of landfill acquisition was not considered.

At about the same time in 1977, Windsor's Council decided that the closed landfill on the city's west side would be converted to a park and golf course. It was estimated then that the cost of obtaining sufficient topsoil to convert the 160 acre site would be some $500,000.

If the composting process generated approximately 10,000 cubic yards of finished compost per year, then it would take 10 to 15 years to complete the conversion of the landfill .... Development of a park now made composting at West Windsor a reality.

THE SITE

The West Windsor Pollution Control Plant was chosen for composting for the following reasons:

1. West Windsor was the largest of the two plants, hence the greatest benefit would accrue in scale of operation as well as ceasing haulage of sludge along city streets.
2. Six acres were available on site for at least another 10 years, on which the composting process could be carried out.
3. The site was 1,100 feet from the nearest homes.
4. The site could be economically drained to sanitary sewer.

The West Windsor Plant produces approximately one ton of dry solids, as sludge, per million gallons of flow treated. This primary/chemical sludge is pumped from the clarifiers to the dewatering building where, at that time, vacuum filters and one centrifuge served as dewatering equipment. The raw sludge had a solids content of approximately eight percent, which was increased to 26 percent when dewatered by centrifuge and 20 percent when dewatered by vacuum filter. Approximately 35,000 tons of wet sludgecake per year required disposal.

It was necessary to receive approval from the Provincial Environmental Assessment Board before commencement of composting. Conditional approval was given by the Board, with the stipulation that monitoring of the compost, both during its preparation and as a finished product,

would be undertaken on a regular basis for determination of pathogenic organisms and heavy metals, and that off-site monitoring be implemented with respect to application of compost on public property.

SITE PREPARATION

On completion of a six month compost trial in 1978, it was proven that this process was feasible. Windsor did not, however, know if the compost process would be a long term method of disposing of the West Windsor Plant's sludge so a minimum of capital expenditure was undertaken for the first phase of the process, which was projected as a five year plan. The City spent approximately $150,000 to prepare a site. Tile drains, with French drains to the surface, were placed on four acres of land to collect leachate and runoff water and return it to the treatment plant. Also, a 100 ft. by 150 ft. concrete pad and an electrical power line to illuminate the area and provide power for the aeration fans were constructed. A screening plant was purchased to recover the wood-chips for recycling into the process.

A decision was made to have the work tendered to the private sector, with close supervision by plant staff, and a five year contract was let. The contractor supplied large frontend loaders, a truck to haul the sludge from the dewatering building to the mix pad, and a tractor and rototiller for mixing the sludge with bulking agents. It was estimated in the contract that about two thirds of the yearly sludge quantity of 30,000 wet tons would be composted. Because of the facility limitations and compost equipment deficiencies, only one half of the yearly tonnage was composted, or 3,400 dry tons per year.

The process, after three and a half years of experience, proved to be a very effective way of recycling sewage sludge. Therefore, when the West Windsor Plant was expanded in 1980-81, it was also decided to

improve the composting site facilities (Fig. 3) based on the experience and observations of the system. The total capital expenditure of $800,000 was warranted as it was estimated then in 1981 that considerable quantities of compost would be required by our Parks Department to the end of the 1980's. Composting could continue indefinitely if the present quality was maintained and markets or end uses other than internal to the City were found in the future. The following capital projects were undertaken in 1981 and also changes to a new second term of the composting contract, which began in May of 1983.

1. An asphalt hard surface area was prepared for the composting area, with good slopes to drainage.

   The original crushed stone pad required a great deal of maintenance to keep good drainage, as the dirt like compost characteristics quickly made the stone surface almost impermeable. In freezing weather there was inadequate drainage of surface leachate, and proper slope and grade maintenance was difficult. There are also approximately 50 gallons per day of condensate to be removed from the ventilation piping to the fans in the first five days of composting cycle, and a very adequate all season system was provided.

2. A covered drying building was constructed about 100 ft. long and 85 ft. wide, with forced air trenches every 5 ft. inside the building.

   Experience in the first four winter and spring seasons had demonstrated that when compost piles were broken down for screening at the end of the 30 day cycle, some of them, or portions of the piles, were too wet to screen immediately. This material could be set aside in the summer and fall months when, with warm weather and little rain, the material would dry enough within three or four

days to screen. However in the cold, wet months the unscreened compost would become wetter as precipitation cooled and soaked the material. Without air to continue the biological heat cell necessary to keep the material warm and expelling moisture, the whole curing pile would become so wet that screening could not take place until summer. The accumulated unscreened compost then became anaerobic, making the screening process very difficult, and causing odours to be emitted at times from the site. Now moist, unscreened compost that is discovered at the end of a compost cycle is placed in the drying building. Air forced through the trenches keeps the biological heat cell functioning -- temperatures occasionally reach 85°C -- and since the material is protected from the elements, the unscreened compost drops below 40 percent moisture within a few days. The unscreened compost, at this moisture, is dry enough so as not to blind or plug the screen openings and the bulking agent can be separated from the compost for reuse in the next mixing cycle.

3. A mix building was built, with a roof and two concrete collector walls.

This building houses the mixed sludge and bulking agent from the elements before placement on the compost pad. Also, a small quantity of bulking agent is stored here in order to have dry mixing material on days of precipitation.

It was discovered that on rainy days, a rain or snowfall could add moisture to the sludge/bulking agent mix and upset the desired initial moisture balance, thereby adversely affecting the subsequent compost process.

The above three entities have made the composting process fully effective throughout the four seasons, facilitating the composting of 7,000 dry tonnes per year without any seasonal hardships.

4. Superior mixing was specified in the new contract by the use of modified agrimixers

The tractor-rototiller going over a layer of one foot of woodchips and four to six inches of sludge previously resulted in a crude mixture and very often an inconsistent bulking agent to sludge ratio. These mobile mixers along with discharge weighing systems for sludge in the new dewatering building allow for precise sludge to bulking agent ratios to be maintained, as well as thoroughly uniform mixture.

5. Rubber chips (chopped scrap tires purchased under contract from Uniroyal) have been acquired to partially substitute for up to 50% of degradable woodchips used in process for bulking agent in latest contract.

Experiments in 1980 and 1981 proved that a large portion of the degradable woodchips could be replaced with non-degradable rubber. This does not adversely affect the process and results in a substantial saving, since the woodchips that break down in the process equate to approximately 20 percent of the wood used in each cycle of the compost process.

WEST WINDSOR COMPOST PROCESS (1983)

The composting process cycle, in brief, goes as follows:

1. The centrifuged sludgecake, at an average solids content of 29 percent, is automatically weighed in to a modified agrimixer, similar to mixers used to mix cattle feed in large batches.

2. A measured quantity of bulking agent (wood and rubber chips) is added by frontend loader to the agrimixer, which is truck-mounted or tractor-pulled. The ratio is from two or three parts bulking agent to one part sludgecake. This ratio is calculated by the City's foreman supervising the contractor, and is based on the moisture content of the sludge and bulking agent. Moisture content should not exceed 62% of the mixture.

3. Mixture is then taken to the compost pad and placed on a base of clean bulking agent approximately 12 to 14 inches deep. Plastic perforated piping has already been laid on the asphalt at eight foot centres. The sections of perforated piping are connected at one end to a fan capable of drawing 550 C.F.M. at a static pressure of four inches of water. Each base is 25 feet wide and 85 feet long.

4. The mixture of sludge and bulking agent is placed by frontend loader from seven to 11 feet high on top of the base (Fig. 1).

5. When sufficient mixture is placed, a blanket of cover material, usually unscreened compost, is placed for insulation purposes.

6. Cross-section of a <u>single</u> pile; see Fig. 1.

7. The three sections of suction piping from the base are connected at the end facing the fan to a solid but flexible plastic pipe. This pipe is extended out from the pile to a drainage tee and U-trap, located over a manhole. The leachate from the trap drips into the manhole, which is connected to sewers leading back to the plant.

8. The suction piping from the drainage tee is then connected to the fans, which are run individually on a fully variable timer-controller. The fans usually run on a cycle of four to 15

minutes on, and two to eight minutes off. The timers are set by the City's foreman and control both temperatures and oxygens in the individual piles serviced by the fan.

9. The air discharged from the fan is very odorous and it is necessary to scrub the air of the malodorous substances. This is accomplished by diverting the air into a scrubber pile made up of screened, finished compost. The compost removes all malodorous elements of the air discharged by fan.

10. The compost piles are stacked or built in series with no space between them. This results in better temperature control, conservation of site space and less cover material. The compost pad is capable of containing 10 piles on each side. About three or four new piles are built each week and also the same number are removed, being at the end of the compost cycle.

11. The composting piles are monitored for oxygen and temperature on a periodic basis, at least twice a week for each pile, to assure sufficient data to prove pasteurization. Temperatures must reach 55°C, or 130°F, <u>throughout</u> the pile for five successive days in order to completely destroy harmful pathogenic bacteria and viruses. At West Windsor, the normal minimum temperature of the piles is 60°C, or 150°F. Generally most of the curing pile cross-section (Fig. 1) reaches 72°C, or 160°F, for a period of over two weeks (Fig. 2).

12. The curing pile is broken down after 30 days of composting. The material is still very warm and a significant amount of moisture is given off as the loader moves the material to screening, or for further drying in the drying building, if its moisture is above 40 percent.

13. The compost is then screened over a 1/4 inch mesh screen in order to recover 85 percent of the original woodchips and all of the rubber chips in the mixture. The type of screening equipment is critical to the whole process, as improper screening plants can almost totally bog down the process if the end step does not keep up with the composting. This paper will not detail the material handling exercise; anyone interested may contact the Director of Pollution Control to discuss this aspect more fully.

14. The finished, screened compost is an earthlike material containing fine wood slivers, and has a composition as shown on Table I and Table II.

    Table I gives a comparison of chemical composition of sludgecake with screened compost. It will be noted that while there is a substantial drop in moisture content in the final product, there is also a slight reduction in nutrient content. Compost is not a fertilizer because of low levels of nitrogen, phosphorus and potash.

    Table II exhibits the heavy metal content in compost and the Provincial guidelines of maximum acceptable metal concentration in compost containing five percent nitrogen or less.

15. The recycled bulking agent (wood and rubber) is replenished with fresh woodchips to make up that which was lost in the finished compost product. It is then reused to mix with the sludgecake as in Step 2.

RECENT IMPROVEMENTS

1. Rubber Chip Use

Presently the percentage of rubber chips (chopped scrap tires) supplanting wood in the bulking agent is 40 percent. Our goal is to reach 50 percent rubber and 50 percent wood as the ingredients of bulking agent in the Windsor process. This partial substitution of rubber in place of wood will result in savings in excess of $130,000 per year, in comparison with using all wood as a bulking agent.

The use of rubber has also produced a favorable compost process enhancement that was unexpected. The result of using rubber chips in the sludge-bulking agent mixture gives a much more open or friable mixture that does not settle and compact nearly as much as an all wood-sludge mixture. This has allowed more uniform air movement through the mix, which gives us a much dryer product at the end of the cycle. Since there are no 'dead spots' in the mixture, it is completely aerobic and thereby much less odour is produced when the composted pile is torn down for screening at the end of the 30 day cycle.

2. Water Scrubber Drum on Ventilation Piping

Previous to this summer, the malodorous gases that the fan drew out of the piles during its operation were scrubbed solely by passing the gases through the scrubber pile. This scrubber pile consisted of fine screened compost. This very effective method was discovered in West Germany and adapted to the Beltsville Aerated Method. The compost must be kept damp, however, for it to be fully effective. A dry compost has little microbial action, and it is this process that adsorbs the mercaptans and sulphides contained in the ventilation gases. In the summer period Windsor's temperatures (over 72^{o}C) were so high that it was difficult to keep the scrubber piles uniformly moist and

odour control was more difficult.

The newest innovation was the placement of a small water scrubber before the fan. In this case it consists of a 45 gallon drum as the outer shell, a spray nozzle using effluent water for spray and the drum packed with plastic tower packing rings. The spray water is directed to sewer, where the ventilation condensate piping is located. This water spray removed 80 percent of the mercaptans, and cools the gases from 72 to 40° C. In this way the scrubber piles remain moist and odours are effectively controlled.

COSTS

The cost to compost sludgecake at the West Windsor Plant in 1984 is less than $17 per tonne, or $59 per dry tonne. This does not take into consideration any amortization costs on the recent $800,000 capital investment, or equivalent value of the compost as a usable product. The expenditure to haul to the city-county landfill is approximately $22 per wet tonne, or $76 per dry tonne. This does not take into account the cost of developing a new landfill, or permanent closure costs of the existing one.

COMPOST USE

In Windsor it is projected that the total compost produced will be consumed by the Parks and Public Works Departments for park development and restoration projects throughout the city.

The City of Windsor was fortunate in obtaining a grant from the Ministry of the Environment that covered about 75 percent of the cost for the first two years of both a demonstration study and an in depth replicated study on clay and sandy soils at the Ridgetown College of Agricultural Technology.

Compost from both Windsor and the MOE's Toronto Experimental Recovery Centre was applied to corn plots and the results of the tests are very encouraging. This third and last year of the study was funded by RCAT, with assistance by the MOE in the use of their laboratory facilities. This study ended with the 1983 corn crop and published results should be available by the end of 1984.

Humus material is in short supply in the cash crop sector of Essex, Lambton and Kent Counties and the demand will be ever-increasing for agricultural use. Compost is an excellent soil conditioner. In sandy soils it stabilizes the earth, preventing wind erosion and adding moisture. In one of the city's parks, Mic Mac Park, an area known as the commons was very sandy and grasses continually died out, especially in the warm, dry weather. The area was treated with an average of four inches of compost, which was rototilled into the sandy top layer of soil and the results have been excellent.

Although there have been no scientific tests done in Windsor, the USDA's experience in the Washington, DC area shows that sod, seeded with compost, is ready for marketing within six months, while sod grown on identical soil and treated and cared for in the conventional manner, takes some 14 to 15 months to mature. It was found when using Beltsville compost that infiltration of water, both in intake per hour and in total intake over a three hour period, increased by more than 50 percent. Also, the quick growth of grasses enabled the respective Washington area Parks Departments to seed many large areas, rather than sod.

Land reclamation is an ideal use for recycled compost material. As mentioned already, Windsor's Parks Department is reclaiming an old land-fill approximately 160 acres in size as a golf course, active and

passive recreation areas and a toboggan slope. The original cover material at this site consists of impervious clay, which is infertile and useless for horticultural purposes. The compost will take the place of over 100,000 cubic yards of topsoil which, if available in this area, would cost today some $1-million.

The Parks Department spreads compost on the existing cover material to a depth of four to six inches and incorporates it into the clay by rototilling and discing. Some areas may require two applications. This would equate to anywhere from 640 cubic yards to 1,600 cubic yards per acre and it is estimated that this one project will require at least 10 years production of compost from the West Windsor Plant. Compost in the U.S. is mainly being used in the nursery horticultural sector and is outperforming peatmoss, especially in the pot plantings of evergreens such as junipers. The City of Windsor only recently obtained permission from the MOE to enter into this market, provided records are kept of its use. The City intends to pursue this market in order to slowly develop a market for future years, assuring a useful, long term consumption of this valuable, recycled product.

CONCLUSIONS

1. Composting of sewage sludge is practical in most urbanized areas of Canada.

2. Composting is a method to treat waste, or recycle waste, which at this point is not a significant moneymaker unless large sums are expended.

3. By composting sewage sludgecake, odours are alleviated and a stable humus-like organic material is produced.

4. The exothermic process generates temperatures within the pile that effectively destroy many of the human pathogens.

5. While composting is more labour intensive than some of the other systems of sludgecake disposal, it is not capital intensive.

6. The composting of sewage sludge is a conserver of energy when compared with other methods of disposal.

7. The end product can be utilized as a soil conditioner in publicly owned parks and recreational areas, and it could also be used by the agricultural industry in the production of field crops if chemically acceptable.

8. The compost process can readily be contracted out or done by City forces.

L. S. Romano, P.Eng.
Director of Pollution Control

TABLE I.

CITY OF WINDSOR

COMPARISON OF CHEMICAL COMPOSITION OF SLUDGE CAKE WITH SCREENED COMPOST.

CONSTITUENT	SLUDGE CAKE	COMPOST
SOLIDS	29·0 %	65·7 %
VOLATILE (% Of Dry Solids)	57·5 %	32·9 %
AMMONIA - NITROGEN	0·18 %	0·28 %
KJELDAHL - NITROGEN	2·3 %	1·6 %
PHOSPHORUS AS P	2·0 %	1·9 %
POTASSIUM AS K	0·07 %	0·1 %

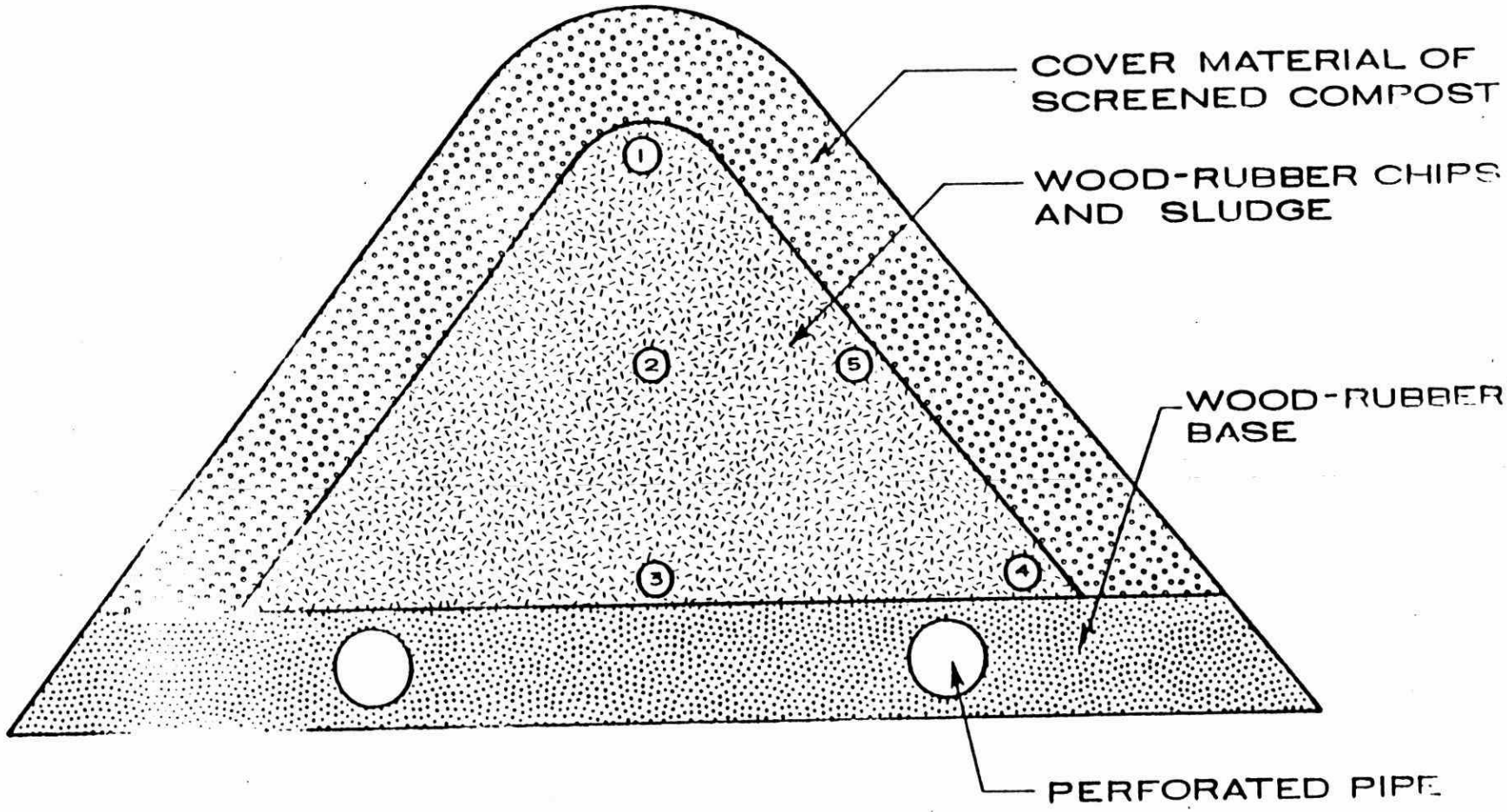
NOTE: TEST DATA REPRESENTS AVERAGE VALUES OF COMPOSITE SAMPLES OF SLUDGE AND COMPOST ANALYZED IN 1982

TABLE II.

CITY OF WINDSOR

HEAVY METALS IN SLUDGE COMPOST WITH RESPECT TO ENVIRONMENTAL GUIDELINES

CONSTITUENT	COMPOST	PROVINCIAL GUIDELINES
CADMIUM	8·2 mg/kg	10·0 mg/kg
CHROMIUM	393 "	1,000 "
COPPER	401 "	750 "
NICKEL	202 "	160 "
LEAD	309 "	450 "
ZINC	1,390 "	1,650 "
MERCURY	2·3 "	4 "



CROSS SECTION OF A COMPOST PILE SHOWING TYPICAL SAMPLING POINTS

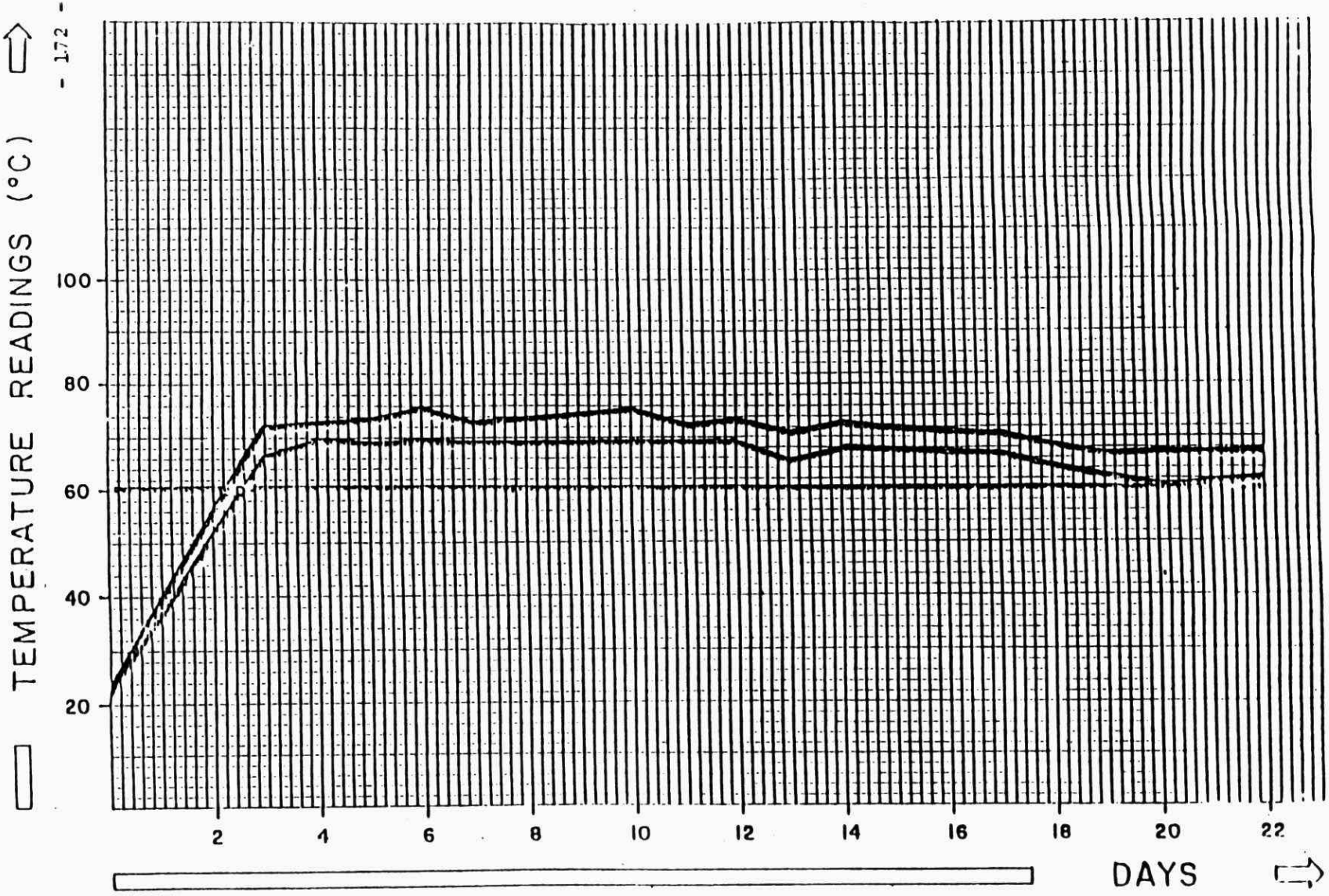


FIGURE 2

AVERAGE & LOW TEMP RDGS. WITHIN WELL INSULATE

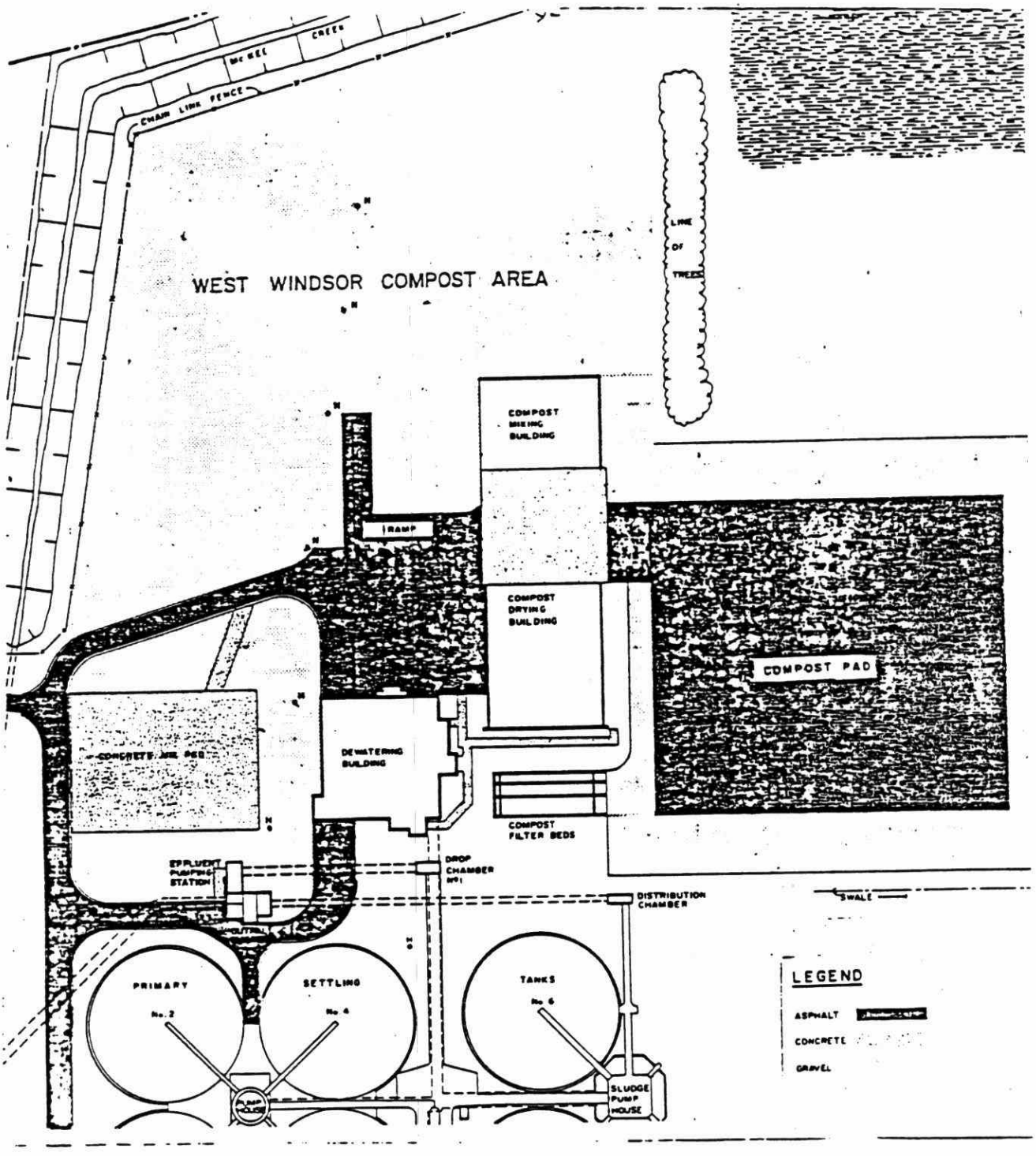

CHAIN LINK FENCE
CREEK
WEST WINDSOR COMPOST AREA
LINE OF TREES
COMPOST MIXING BUILDING
RAMP
COMPOST DRYING BUILDING
COMPOST PAD
DEWATERING BUILDING
COMPOST FILTER BEDS
EFFLUENT PUMPING STATION
DROP CHAMBER
DISTRIBUTION CHAMBER
SWALE
PRIMARY
SETTLING
TANKS
SLUDGE PUMP HOUSE
LEGEND
ASPHALT
CONCRETE
GRAVEL

FIGURE 3

THE DOWNSVIEW COMPOSTING OPERATION

EXPERIMENTAL RESOURCE RECOVERY PLANT

By: Peter J. Provias[1]

Background

The Ministry of Environment (M.O.E.) in 1974, announced a **"Comprehensive Resource Recovery Program" a waste management policy designed to take it through to the 1990's. This Program consolidated the various waste management initiatives undertaken since the Waste Management Act of or 1970.

In essence it was a policy to:

- Reduce to a minimum the use of land for waste disposal
- Recover resources from waste and maximize their recyclability.
- Reduce the quantity of waste produced.

To achieve these goals it was proposed to adopt one of several emerging resource recovery technologies; one which would have the potential for maximum recyclability of materials and/or energy recovered from municipal solid waste (M.S.W.). The resource recovery process would be state of the art technology.

** Objectives of program now an integral part of the "Blueprint for Waste Management in Ontario.

1 Market Development Engineer, Waste Management Branch, Ontario Ministry of the Environment.

Accordingly, the Ministry built the Experimental Resource Recovery Plant (E.R.R.P),[I] representing at that time a state of the art technology. This would allow the Ministry to:

- Evaluate resource recovery technology
- Recover useful materials from M.S.W.
- Evaluate and develop not only markets for the recovered material but also the appropriate quality for such resources.

The official opening of the Experimental Resource Recovery Plant (E.R.R.P) was August 1, 1978. It is located on a 7 hectare site (18 acres) in Downsview a part of the City of North York, in Metropolitan Toronto.

The plant as shown (Fig. I), designed by Kilborn Engineering Toronto, retains the capability of modular progression with facilities for development programs undertaken either by government or industry.

The (E.R.R.P) consist of three buildings other than the scale house (not shown).

Building 1 - Receiving, Transferring, old corrugated cardboard recovery, shredding, air separation

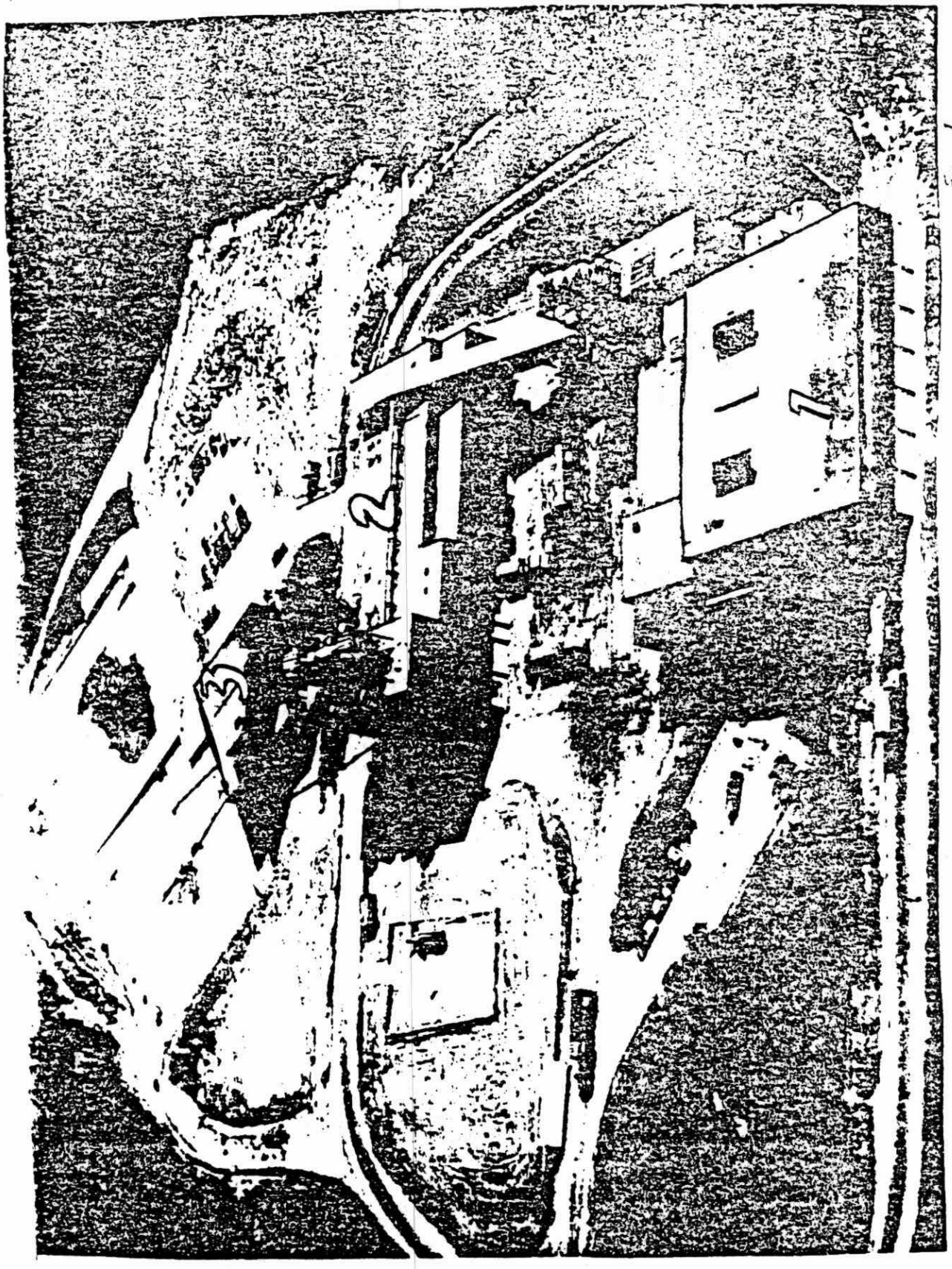


Fig 1

Building 2 - Commodities & Energy Recovery and loadout

Building 3 - Composting

The alternative of turning the organic fraction of M.S.W. into a final composted product after the recyclable material had been removed including material destined for energy usage, was recognized by the Ministry of Environment (M.O.E.). This option was incorporated as one of the modules (Building 3). It was the first resource recovery plant of its kind which included a continuous automated enclosed system to compost municipal solid waste (M.S.W.) and/or digested sewage sludge.

The digester, the heart of the composting process located in Building 3 was chosen by Kilborn over 5 other systems available at that time. The digester[II] is a Fairfield model engineered by Fairfield Engineering, Marion, Ohio, U.S.A. and represents an enclosed continuous mechanical system.

The focus of this paper is the composting operation but before getting into this, the E.R.R.P. operations will be briefly described.

PLANT DESCRIPTION

All waste processing through the Experimental Resource Recovery Plant except the composting module is done on material as received and the equipment was designed for average capacity of 36 metric tonnes/hour (40 TPH) with a peak capacity of 54 metric tonnes (60 TPH); the plant was also designed to receive an additional 550 m tonnes (600 tons) daily in a single shift and transfer out this tonnage without processing in 57 m^3 (75 yd) compaction trailers for hauling to land fill sites. The direct transfer facilities not only provide immediate services to the area but also increase the overall versatility of the plant.

The in-line processing of the (E.R.R.P) carried out within the three buildings are: (Fig. 2)

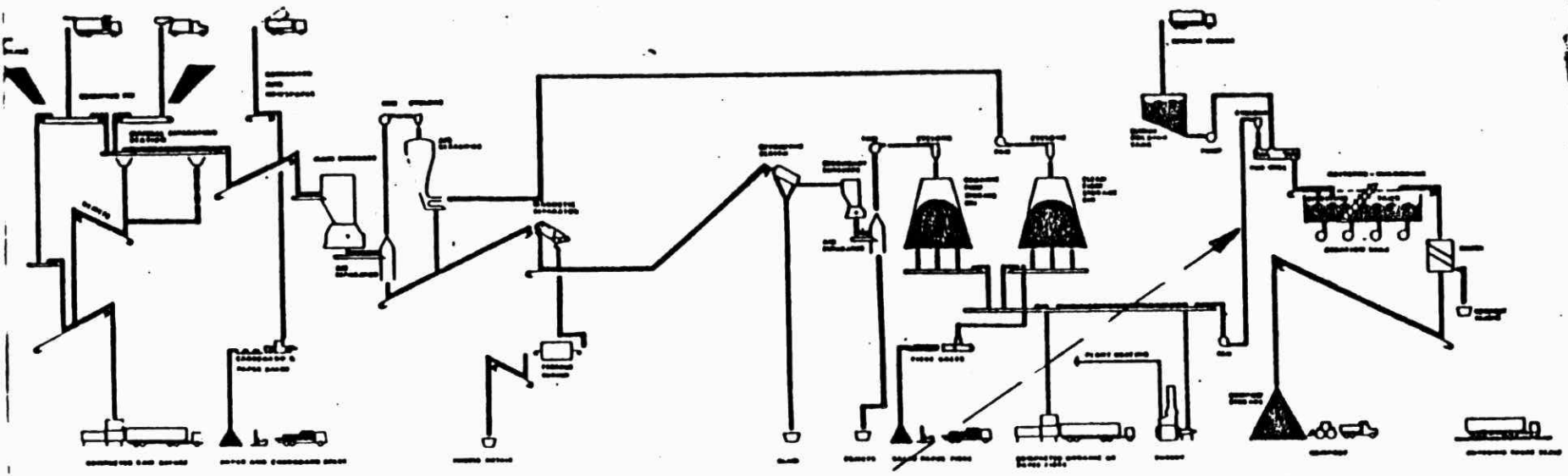
Building I	Receiving, Transfer, cardboard recovery Primary Shredding air separation
Building 2	Material recovery; magnetic separation, Trommel Screening, secondary shredding organic separation, energy recovery
Building 3	Composting Operation

RESOURCE RECOVERY
ONTARIO MINISTRY OF THE ENVIRONMENT

EXPERIMENTAL PLANT
FOR RESOURCE RECOVERY

PROCESS FLOW DIAGRAM

FIG. 2



ORGANIC RICH FEED

Fig. 1

PREPARATION OF FEED

The organic rich feed stock required for the composting process is pneumatically conveyed to the Composting Building from Building 2 as shown (Fig. 2). This feed stock is the result of the following series of steps shown in (Fig.3).

Fig. 3

PREPARATION OF ORGANIC FEED
(E.R.R.P)

Primary Shredding
Primary Air Separation/Classification
Magnetic Ferrous Separation
Trommel Screening
Secondary Shredding
Secondary Air Separation

|

ORGANIC RICH FEED

|

COMPOSTING BUILDING

Prior to being fed to the Digester tank, the organic rich material from the Commodities Building (2) when delivered to the Composting Building (3), is mixed with water and/or digested sewage sludge along with small amounts of urea (45% nitrogen) the latter being added for nitrogen value.

SLUDGE AND UREA ADDITIONS

In the Composting Building, there are facilities for handling sludge - a holding tank below ground level and a pumping station at ground level. The sludge is pumped up to the second level above the digester to a Sprout-Waldron pug mill where all mixing takes place. Sludge is added for the following reasons:

- To investigate co-composting with municipal solid waste (MSW).
- To add some residual nutrients (nitrogen, phosphorus and trace elements to the feed.
- To add the required moisture to the composting system.

We have discontinued sludge additions for the time being after the closure of our sludge source, a sewage plant just north of Toronto. No decision has been made for an alternative source. Other factors have to be considered; e.g. the degree to which sludge has been dewatered since it

would be to our advantage to have at least 20/25% solid rather than the 2% we had been using; and the level of trace contaminants within the sludge. Our experience with sludge as a digester feed proved that it can be successfully co-composted with MSW.

Urea (45% nitrogen) was added to increase nitrogen content in order to keep the carbon: nitrogen ratio in its proper perspective for the composting process, i.e. low enough to prevent "soil robbing". About 0.13% urea by weight was added to the wetted feed at the pug mill; although the addition was suspended temporarily in order to study its effect. Comparative nitrogen values under both conditions are shown (Table I)

Without urea, nitrogen dropped slightly as one would expect. Currently, under consideration is the cost/benefit of urea against other sources of nitrogen, although in all likelihood, we will resume the urea addition since it does appear to be the cheapest source of nitrogen available.

Organic Rich Feed

Averaging about 35% to 40% of the total solid waste stream entering the plant, the organic content has remained relatively stable despite the fact that the waste has come

TABLE I

UREA		NO UREA	
Compost Feed	Twin Deck Unders 1/2"	Compost Feed	Twin Deck Unders - 1/2"
PH % Nitrogen	PH % Nitrogen	PH % Nitrogen	PH % Nitrogen
5.7 0.89	6.6 0.85	5.7 0.71	6.7 0.69

primarily from two different sources; Commercial/industrial waste from 1980 through 1982 and household waste from 1982 to the present.

Some of the characteristics of the feed stock from both sources are shown (Table 2).

Equally important for the feed stock is the level of "heavy metals", a level which in fact, if too high could restrain the usage of the end product.

There are eleven (11) of the heavy metals that are considered potential contaminants; hence the need for a maximum allowable level.[III] These are monitored closely and our experience to date is that we have few problems staying within the allowable guidelines and in fact have seen little difference in the level of heavy metals regardless of the source of organic feed stock. (Table 3)

The addition of digested sewage sludge to the organic rich feed stock had little effect on the final levels of heavy metals simply because we made sure our sludge came from a plant servicing a residential area inherently low in heavy metals.

Table 2

CHARACTERISTICS OF ORGANIC

FEED STOCK

SOURCE OF ORGANICS

	Commerical	Residential
PAPER	32%	29%
Ash	26%	25%
Moisture	24%	31%
Plastics	18%	15%

TABLE 3

HEAVY METAL CONTENT

ORGANIC FEED

P.P.M.

	COMMERCIAL	ALLOWABLE LEVELS	RESIDENTIAL
ZINC	605	1650	489
ARSENIC	2.4	70	2.4
CADMIUM	4.5	10	4.7
COBALT	4.8	150	4.1
CHROMIUM	157	1000	83
COPPER	402	750	139
MERCURY	2.2	4	3
MOLYBDENUM	14.1	20	8.5
NICKEL	56.6	160	38
LEAD	585	450	292
SELENIUM	0.5	12	0.22
BORON	27		

Composting System

The schematic of the composting process (Fig.5) shows what happens when the organic feed enters the composting building through the 16" diameter pipe from the commodities building.

The feed is discharged into a cyclone equipped with a baghouse and rotary air lock. It then drops into a Sprout-Waldron pug mill as mentioned previously where it mixes with water or waste water sludge along with urea to obtain a moisture content of 60%.

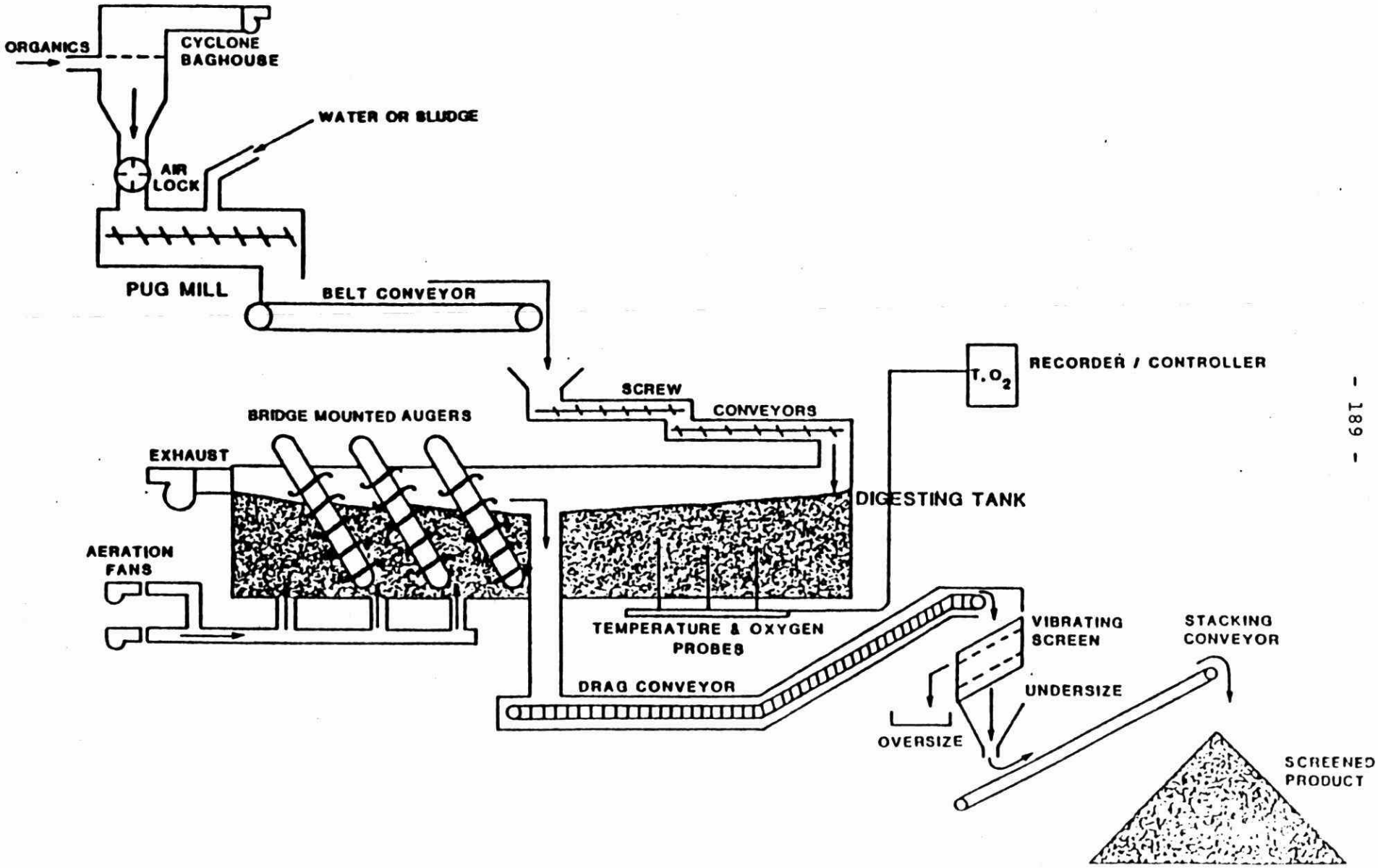
The organic rich feed stock before entering the pug mill has an average moisture of 30%. Each day, 30 metric tonnes of this material is mixed with 20 tonnes of water or sludge (98% water) to produce a mixture with an average moisture content of 60%.

The material is fed to the digester at the rate of 50 tonnes per day, 5 days per week with a retention time in the digester of 7 days.

About 40 tonnes of partially stabilized compost is discharged for each 50 tonnes of material fed to it. The 10 tonne loss is due to loss of water either as vapour or small amounts of leachate and to carbon loss as carbon dioxide (CO_2).

COMPOSTING SCHEMATIC

FIG. 5



The discharge of 40 tonnes is screened on a double deck rubber screen of 25mm (1") and 12 mm (1/2") to produce 20 tonnes of the minus 12mm (1/2") material which is stored for final curing.

The 20 tonnes of oversize +12 mm (1/2") can be treated in several ways: (Table 4)

1. Recycle back to system

2. Rescreen and windrow

3. Windrow for final curing

4. Discard to Land-fill

DIGESTER OPERATION

Wetted feed material is moved to the circular digester tank by belt conveyor and deposited at the periphry of the tank by a series of 2 screw conveyors. The digester is equipped with 13 bridge mounted inclined augers on a rotating super structure. (Fig. 5)

The circular tank is 18m (58 ft) in diameter, poured reinforced concrete and 2.5 m (8 ft.) deep. It will hold 250 tonnes of organic pulp (50 tpd for 5 days).

The revolving augers attached to the rotating bridge both mix and move the 2.4 m. deep mass of composting material from the periphry wall to the centre of the digester where the material overflows into the discharge weir. All of the digester machinery except the air blowers stop when the pulp is not flowing into the digester. An additional back-up blower installed as a modification automatically activates should the primary blower fail.

To ensure that the compost is maintained at the proper temperature and oxygen conditions during the digestion period, one of two 130 m^3 (4500 c.f.m) blowers provide air to the process through an air distribution system in the bottom of the tank. The air flow is controlled by

temperature and oxygen sensors located at various points within the digester. These sensors retreat prior to the augers passing over them to prevent them from being sheared off.

The off gases generated by the composting process such as water vapour and carbon dioxide (CO_2) are not permitted to discharge freely into the compost building. The entire digester has been covered and an exhaust system mounted around the side-wall of the digester vents the gases from the building.

After the organic material has passed through the digester and drops out the discharge weir, a 37 meter long drag conveyor carries the crude compost to a vibrating twin deck equipped with 2 rubber screens with square holes 25mm (1") over 12 mm (1/2"). The minus 12mm (1/2") material discharges on to a concrete pad by a stacking conveyor.

A front end loader moves the compost into the storage piles for final curing.

Process of Composting

Decomposition of the organic material requires a system design which will control the levels of moisture and (oxygen). From past experience, low moisture levels < 45%

can cause reduction in biological activity since it does effect the movement of nutrients. Too much moisture > 60% can reduce the permeability of the material since pockets of air present in the mass could be displaced by water thus limiting the amount of oxygen available to the organisms and cause the whole process to go anaerobic.

For this reason, the ingoing moisture content of the Digester feed material was normally kept between 55 and 60%. However, we are now lowering our moisture to a level of 50/53%, to minimize a potential leachate problem within the digester as well as making it easier to screen the final product.

Bacteria in the presence of oxygen (aerobic) decompose organic matter and in doing so generate heat. Decomposition in the absence of oxygen (anaerobic) also generates heat but not to the same extent. The rate of decomposition is affected by the amount of oxygen present. Under aerobic conditions decomposition is faster therefore, by controlling the amount of air (oxygen) to the composting mass we can control the rate of decomposition and the temperature level. However, care must be taken to avoid too much air since this can cool the composting mass excessively.

Controlling the temperature and oxygen levels in the Digester is accomplished by two 4500 C.F.M. blowers which provide

forced air 24 hours per day into the pipes imbedded in crushed stone at the bottom of the Digester tank. These pipes 8", 4" and 3" in diameter, feed the outer, middle and inner zones of the tank respectively.

Each zone has a retractable probe with temperature sensor and oxygen inlet. The temperature and oxygen set points are scanned by a programmer, with adjustments being made automatically. A single oxygen analyzer sequentially determines the % oxygen in all three zones. Both temperature and oxygen recorders are equipped with upper and lower set-points.

Our temperature set points are 65/70°C and oxygen level points are set at 12% to 18%. Maintaining temperature and oxygen levels between these parameters appears to provide for the optimum decomposition rate.

During the composting process, carbon compounds break down or are biologically combined to ultimately form carbon dioxide (CO_2), water, ash and humus under aerobic conditions. Therefore, the percent carbon during composting decreases while relative percent ash increases. The rate change of % carbon can be used to reflect the rate at which the composting process is proceeding.

In looking at Table 5, we see that the carbon content during the 7 day retention period decreased from 37% to 32% while

TABLE 5

	ORGANIC STREAM	FEED TO DIGESTER	DIGESTER DISCHARGE	SCREENED UNDERSIZE	CURED PRODUCT
MOISTURE	28	58	50	50	50
* ASH	26	26	35	40	57
* CARBON	37	37	32	30	23

* DRY BASIS

ash increased from 26% to 35%. Screening to minus 1/2 inch (12mm) further reduces the carbon to 30% and increases the ash to 40% because there is a proportionally greater amount of inert material in the fines which are retained in the compost product.

Additional curing of the windrow piles by turning each month, further reduces the carbon to 23% and increases ash to 57%.

PROBLEMS AND MODIFICATION

Initially design feed rates to the digester could not be achieved primarily because of material handling problems in the feed system.

Table (6) is a list of problems and corresponding solutions which were applied to the feed system.

Table 6

Problems in the Feed System and Their Solutions

1.	Jams in in pneumatic conveyor pipe	Installed fluidizing far at pick up point.
2.	Excessive wear on baghouse pneumatic fan.	Relocated fan to cyclone discharge.
3.	Air discharging from bottom of cyclone/baghouse	Installed rotary air-lock.
4.	Jams in Sprout-Waldron pug mill	Enlarge the area above pug mill.
5.	Slip stick conveyor feeding digester had low rate	Replaced with troughed belt conveyor.
6.	Jams in digester screw conveyors	Increase speed of screws and enlarged openings at discharge points.

The digester itself required changes from the original installation in order to permit design feed rates to be achieved.

1. Bridge speed increased to alleviate the build-up of compost below the feed screw conveyor.

2. Speed of augers increased to move the material faster.

3. Flap placed near the top of the inner auger to help push the material through the discharge weir (at the centre of the digester).

4. All the weirs around the well were removed to prevent material from bridging.

Since these changes, the Digester through put capacity increased to a consistent 50 tonnes per day on a single shift basis.

The forced air control system also required changes, since the original automated system did not perform properly. The various automatic checks such as the rotary step controllers had to be synchronized to permit proper control.

Other changes in the automated system:

1. A fail safe interlock system was installed to protect the retractable probes from being sheared off by the augers.

2. The original oxygen 0_2 meter was replaced by a more appropriate 0_2 analyzer* relocated from beneath the digester to a less corrosive environment in the compost building.

3. Water traps were installed inthe air sampling lines to protect the 0_2 analyzer from water discharge.

After that, the automated system provided, consistently, conditions that were properly controlled within the digester.

As in most start-ups, there was considerable time expended solving all these problems. The end product naturally went through a transition stage to a point when we finally felt confident about the physical and chemical characteristics of the compost.

*Sybron/Taylor
"Servomex" 0_2 Analyzer
541A Model B.

Screening

The digester discharge contains excessive amounts of non-biodegradable materials e.g. plastics. Although we pass the product over a double deck screen 25mm (1") over 12mm (1/2"), the minus 12mm (1/2") material still contains plastic. Although not harmful in use, the plastic does detract from the visual aesthetics.

We went through some screening changes. The original wire mesh screen was exchanged for punched steel plate 25mm (1") and 12mm (1/2"). Throughput still suffered because of the smaller numbers of openings, even though "blinding" of the screen was reduced.

Rubber screens were finally put in service and because of their flexing action, blinding has been reduced and out put increased.

Still, plastics are retained in the minus 12mm (1/2") product. Various options are being considered to remove this plastic.

1. Double deck rubber screens but with a 6mm (1/4") lower screen. This effectively removes plastic but reduces output another 50% from the minus 12mm (1/2") product.

Increasing the production through put to 100 cu. yds per hour ($75m^3$) on large scale screening equipment can keep pace with the digester discharge rate. This has already been demonstrated on large scale mobile screening equipment.

2. Investigation of other methods; air tables, electrostatic separation as well as several other types of screens now on the market.

3. A high speed mixer and pulper in place of the pug mill.

4. Modification of the trommel screen preceding the secondary shredder and air separator.

5. Pelletizing the compost product with subsequent granulation eliminates the visual presence of plastics. Although it adds a cost to the processing, the resultant product would be now more storable and shippable and becomes a more likely candidate for up-grading and value adding.

Post Digester Curing:

Screened Digester discharge with an apparent high C:N ratio is only partially stabilized, a fact we were able to establish not only from the appearance of the discharge material but also subsequently by the continued action in the storage piles.

The average carbon content is 32%, the nitrogen is 0.9% making a C:N ratio of 36:1 In order to reduce this high C:N ratio, we have to sustain the bioligical action that had been going on inside the digester, by utilizing one of several post digestion curing methods.

1. Placing compost in large storage piles
2. Forced aeration in static piles
3. Windrowing with turning

In order to assess the relative rate of curing or decomposition by these methods, the rate at which the % carbon decreased was determined for each method. Presumably the method which showed the most rapid decrease in carbon would be the method which stabilizes the compost the fastest.

1. Storage Method

This requires least amount of effort. The compost is placed by the stacker in large storage piles (e.g. 4 m high x 10 m wide x 20 m long). Anerobic conditions develop since the piles are not turned over to expose the material to air and diffusion is insufficient to penetrate the large pile.

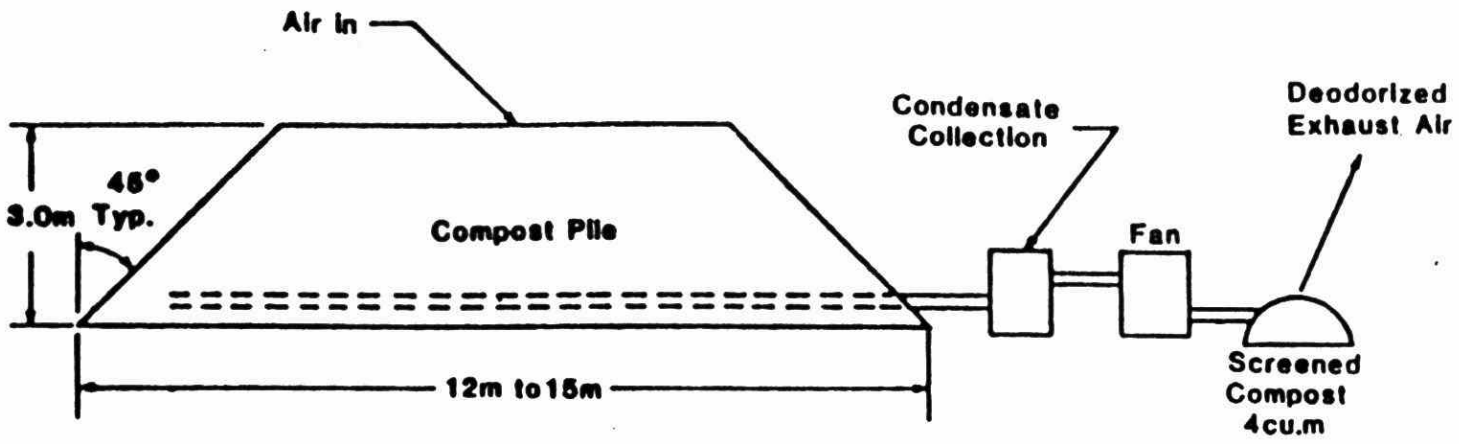
Piles have been left unattended for 4 months and the rate of decomposition during this time is about 1/10 the rate occuring in the digester. Pile temperatures were normally between 50°C and and 60°C for the first two months, but after 4 months, these temperatures dropped off. Generally, after 4 months, these piles have decreased to less than 40°C. The rate of change of carbon by this method was 0.06% per day.

2. Forced Aeration Static Pile:[IV]

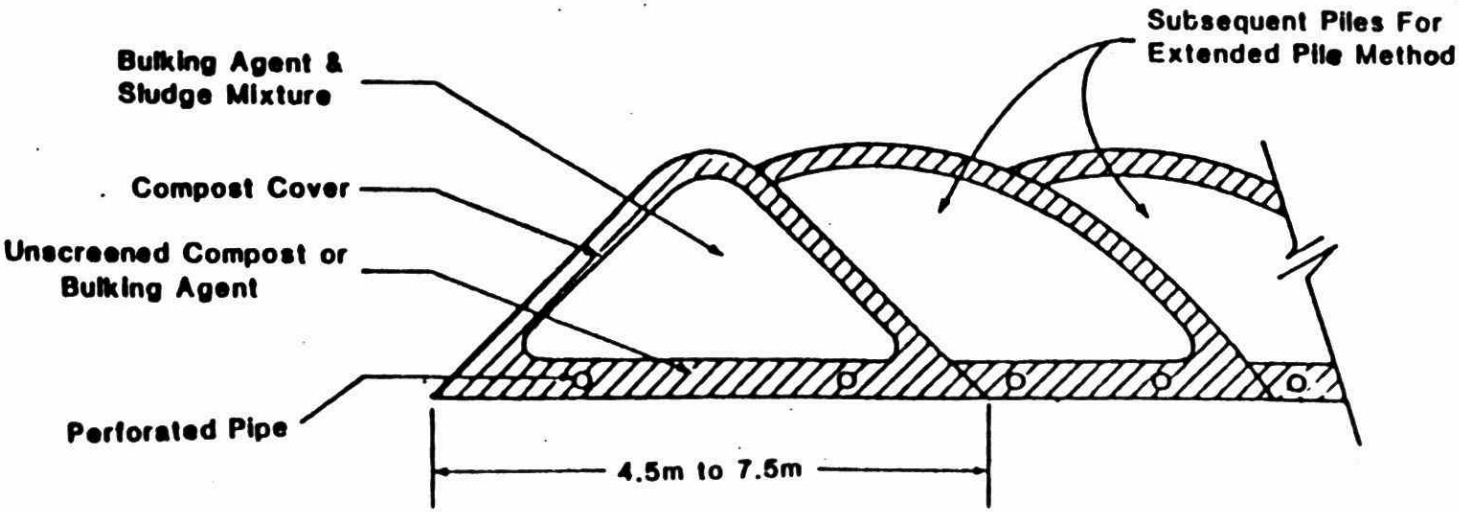
This method has been used extensively in composting dewatered sewage sludge. It increases the rate of decomposition and reduces odour problems. A typical forced aeration sludge composting process is shown (Fig.7).

FIG. 7

TYPICAL FORCED AERATION COMPOST PILE FOR $40m^3$ OF DEWATERED SLUDGE (Reference 4)



GENERAL LAYOUT



CROSS SECTION

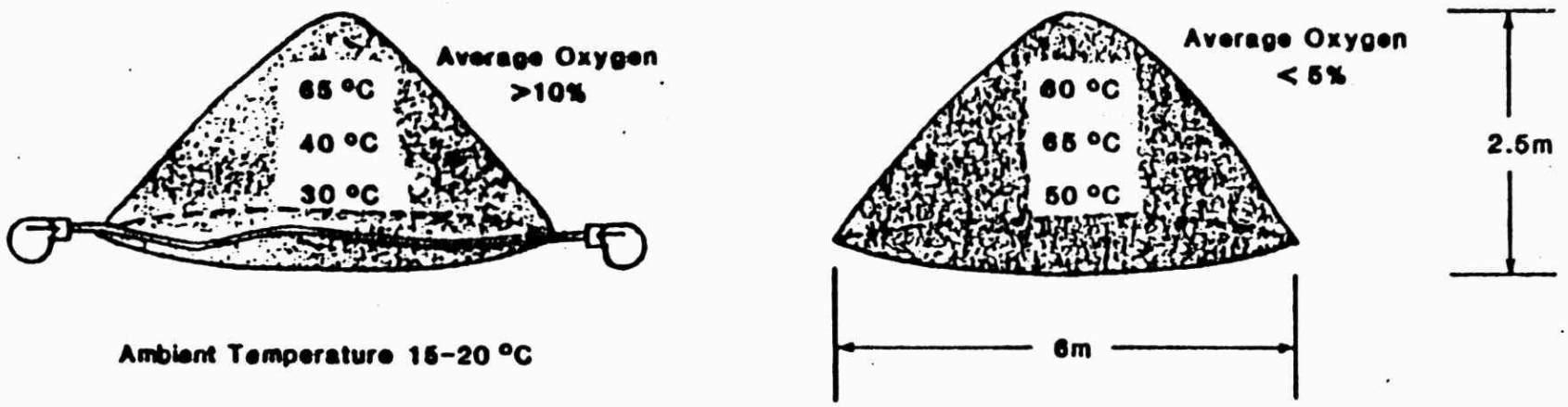
However, we had to alter this technique slightly for the compost produced at the E.R.R.P., because of the fact that we screen immediately following the discharge from the digester. Consequently, the product going to the aeration piles was the finer -12mm (-1/2") screened compost.

Since bulking agents were not used, we were not sure how the air would move through the piles. In the suction mode the fans drew little air through and reversing for positive flow caused the air to penetrate better. However, the air did not diffuse evenly throughout the pile. The material nearest to the perforated pipes received too much air causing it to dry excessively while material further away from the pipes did not receive enough air. Monitoring temperatures and oxygen values became very difficult since the values varied considerably through out the pile.

Like the storage method, the rate at which the carbon decreased by this method was 0.06% per day. Bacterial activity no doubt ceased in the areas next to the perforated pipes where there was low moisture content. (Fig. 8)

Increasing the permeability of the forced aeration pile would improve the situation and this is why bulking agents are used (wood chips, rubber, M.S.W.) when the

GENERAL COMPARISON BETWEEN AE-RATED AND NON-AERATED TEST PILES



method is applied to sewage sludge. Before doing this however, we decided to look at simple windrowing with frequent turnings.

The forced aeration process does reduce odours commonly associated with anerobic conditions. Non-aerated piles had a noticeable odour, but it was by no means severe.

Windrowing (with turning)

This method involves placing the compost in large windrow formations and turning them at regular intervals with a front end loader. Under these conditions, the composting rate is greatly affected by the frequency of turnings. Rate of decomposition in the piles that are turned once per month is about 0.07% carbon per day. Turning the pile every 3 days increased the rate of decomposition to about 0.2% carbon per day. Although we have adopted a one month turning interval on the windrows, it is conceivable that we will go to a 2 week turning cycle.

Labour required to turn the piles may appear to be excessive. But at the E.R.R.P., this is not the case, since the compost building operator is not continuously tied up with the automated system. While the digester

continues to run, the operator is free to turn the piles.

In summary, in our case, windrowing with turning seems to be the most cost effective way to cure compost:

- It incorporates air into the pile to reduce anaerobic conditions
- It produces a uniformly stable product.
- It eliminates use of a bulking agent and consequently its cost of recovery.

PRODUCT CHARACTERISTICS

The finished compost produced at the ERRP is a uniform brown-black material which has a musty or slightly earthy odour. It has a humus-like texture making it suitable as a organic soil conditioner and potentially as an ingredient of various soil mixtures.

Chemical and physical tests are routinely tested on the compost. The results are shown (Table 7)

TABLE 7

CHEMICAL AND PHYSICAL PROPERTIES

*Nitrogen	0.9% (dry weight)
Phosphorus	0.3 " "
Potassium	0.4 " "
Sodium	0.4 " "
Carbon	23 " "
Boron	28 " "
Moisture	55% (wet weight)
Bulk Density	500 kg/m^3
Water Holding Capacity	3 X Dry Wght.
Conductivity	180 millimhos/cm

*Total Kjeldahl Nitrogen

Carbon and nitrogen values are important. General rule is that the C to N ratio of a good compost should be 25:1 or less. Ideally, this C/N ratio should be determined from the available carbon and the available nitrogen values.

The present carbon (23%) of the final product is a direct result of the biological stabilization which has occurred during the composting process. Carbon can be used to indicate the degree of stabilization for a given feed material. We have already seen that carbon can be related to ash content and in our experience, the following relationship between carbon and ash was established:

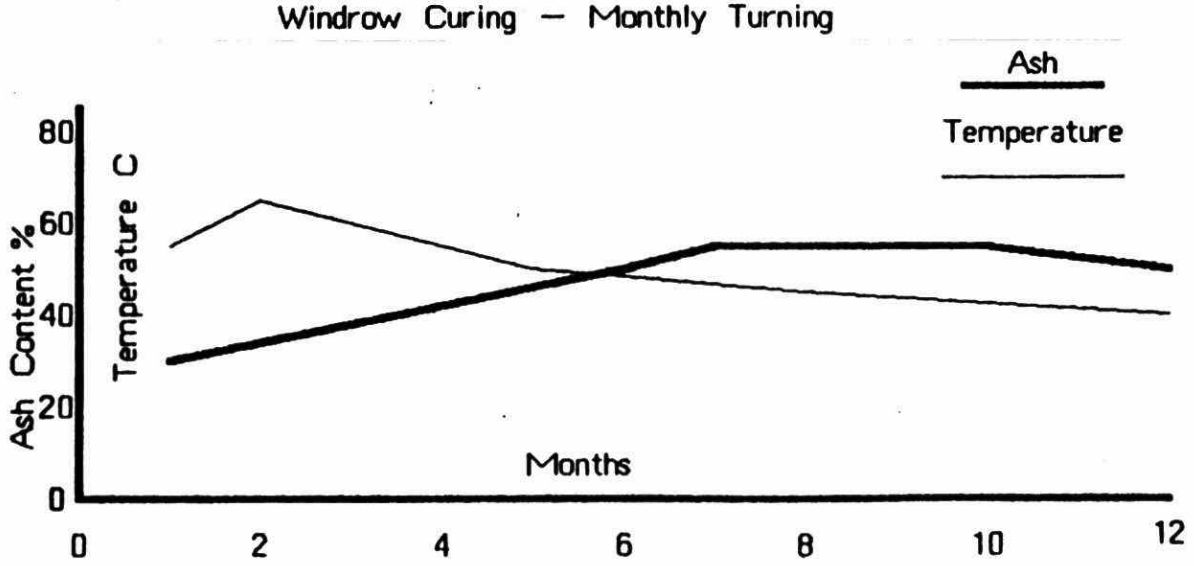
$$\% \text{ carbon} = (46.1) - 0.406\ (\% \text{ ash})$$

As the compost decomposes, the volatile solids decrease causing the percent ash to increase. Compost at the ERRP can be considered adequately stabilized when the ash content is about 55%. In our post-curing treatment in the windrows, (Table 5A), we have seen the levelling off of the ash content along with the temperature stability. Based on that along with the appearance of the product, we consider the product adequately stabilized.

Phosphorus and potassium residuals average 0.3% and 0.4% respectively, typical of this type of compost, with some contribution toward nutrient values.

Table 5 A.

Post Digester Curing



The pH of the final compost product of the ERRP averages 7.9 a satisfactory level for most applications.

The organic feed material to the digester has an average moisture of 58%, while the average moisture content of the cured product is about 50%. However, the ingoing moisture has now been reduced to about 50/53%, with the intent of lowering the final moisture of the cured product to about 40%.

This would be more desirable because of:

- Minimize potential digester leachate
- Improved screening
- Reduced anaerobic odours.
- Reduced shipping costs.

Lowering moisture can be accomplished by:

1. - Decreasing water in the feed material
2. - Increasing retention time in digester
3 - Turning windrows more frequently
4. - Blowing air through the piles.

We are doing 1 and 3 as being the most practical.
Conductivity tests are conducted as a routine quality control test using a Salts Meter Model MC70 (Plant Product Ltd.). The average reading is 175 X 10^{5} uhmos per cm which is near the upper limit of the acceptable range.

In peat like soil, the acceptable range is 100 to 180 apparently satisfactory for general plant growth and a good range for plants fertilized at every watering.

The water holding capacity of the ERRP compost is 3 time its dry weight. This is an important soil-conditioning property. Sandy soils enriched with compost will hold moisture better. Clay soils become more friable thus dispersing water more evenly.

Bulk density determines loading capacity. The average density at 50% moisture is 500 kg/m^3; increases slightly when loaded on trucks.

PATHOGENS

Pathogenic organisms (bacteria, fungi, parasites) found in municipal solid waste (M.S.W.) and/or sewage sludge present potential health problems.

Aerobic composting can deal with these organisms effectively by developing and maintaining a high degree of biological activity. The pathogens are killed by the sustained exposure[V] to the temperatures of 55°C or higher for at least 3 days. Death apparently occurs at various temperatures depending upon the organism, however, the concensus is that 55°C will take care of all pathogens if they are continously exposed to this temperature for at least 3 days. The continuous mixing under aerobic conditions producing the thermophylic stage during the 7 day retention period in the digester ensures proper exposure. In this respect, the Fairfield Digester at the ERRP because of its mixing action would appear to be superior to windrowing or turning piles at least for the early stages of the decomposition process.

The most prevalent organisms of concern can be assumed to be present in the organic digester feed. We have not isolated any one species from a suggested list according to the literature. However, we did subject the finished compost to our laboratory in Rexdale (Toronto), where levels of major indicator groups (Table 8) were determined.[VI]

TABLE 8

MICROBIOLOGICAL ANALYSIS

Some Indicator Groups

Analysis Technique		Count/Grms. (Wet Wght.)
Total Coliforms	M.P.N.	220
Fecal Coliforms	M.P.N.	220
Fecal Streptocci	M.P.N.	3
K-pneumoniae	M.P.N.	4
Heterotrophic Bacteria	M.F.	450×10^6
Fungi	M.F.	70,000

The low numbers for the total coliforms, fecal coliforms and fecal streptococci indicate potential enteric pathogens are not likely present. Fungi and heterotrophic bacterial counts are normal.

The ERRP compost was examined for potentially harmful organic contaminants. Gas chromotography techniques were used and calibrated to detect 38 common occuring contaminants. The chemical compounds in the compost should be classified into two groups:

- Aliphatic and Aromatic Hydrocarbons - 0.29 mg/kg
- Halogenated Organics - 0.006 mg/kg.

These levels are very low and should not likely cause any health problems. To bring these values into perspective, the permitted level in Canadian drinking water for halogenated organics which are considered to be more toxic than hydorcarbon is about 50 times greater than the amount detected in the compost.

Marketing

Over 20 years ago, large scale composting of municipal solid waste (M.S.W.) was considered the answer to waste disposal problems, but such attempts invariably ended in failure simply because the cost per ton of compost exceeded the cost of land-filling. Generally, waste disposal, waste reduction and tipping fee credits were not applied to the cost of compost. The only credit being that derived from the sale of the material which in many cases was limited. Market development effort for most early composting operations was minimal and inadequate.

Again in the past, markets were scattered, generally incurring excessive haulage costs for a product which had little credibility and value added features. In many cases, compost was considered a product to be given away for the cost of haulage.

Today, the rapid depletion of suitable land for sanitary land-fills along with increasing costs of waste disposal could well be the impetus needed to create interest again in M.S.W. Composting as one option for waste management.

The Downsview compost[VII] has the following characteristics which are both desirable and beneficial to potential users.

1. Disease carrying organisms have been destroyed by the high digester temperatures.
2. Consistent texture.
3. Texture (humus-like) suitable for additions to clay and sandy soils.
4. Some nutrient values (N.P.K.)
5. Salt content controllable
6. Low heavy metal contents
7. pH - over 7.0

On the other hand, there are some restraints that have to be overcome. These are:

1. Compost by nature is a seasonable product and most market development is governed by this fact. The short planting periods of Spring and Fall are normally busy for those involved in landscaping, gardening, horticulture and of course farming in general.

2. Field research with the compost must also be conducted during the short busy periods and could even be extended over several seasons. Greenhouse Research which can go on year round should be augmented by field trials. These field trials

however are again, usually restrained by the short growing seasons.

3. Potential users are reluctant to consider even a controlled processed compost for any use without first having an indication of its effectiveness.

4. Although organic compost has some nutritional value it is not, as a lot of people think, a complete organic fertilizer. Competitive materials in the market place; fortified soil mixes, manures, inorganic chemical fertilizers are quite reasonable in price per unit of nutrient.

5. The Downsview Compost when screened through 1/2" screen, retains small pieces of plastic. This plastic is a visual deterrent to further market development and needs to be removed, a step which requires additional processing or a change somewhere along the system.

Since the mandate given the E.R.R.P was, among other things, to develop markets for recovered products; (e.g., compost) and not necessarily to maximize sales of these products to any one user, a normal approach to market development could not be taken. For instance haulage costs, a primary consideration initially were not a determining factor since

trial lots of product had to be placed to parts of Ontario other than Metro Toronto area otherwise, we would not be fulfilling our mandate.

Before the composting module was on stream, we felt an overall look at the Ontario market was needed, so a plan was developed to:

- Carry out a macro study of potential users
- Develop a communication/publicity plan
- Select several areas for micro studies
- Arrange trial lot shipments if necessary
- Develop research and field demonstration trials
- Establish market values

The first part of that program was done before we had a product. Since the composting module was the last part of the plant brought on stream and many modifications were made to the plant processes, there was a long transition period before a marketable product was available.

In 1976/77, a macro market survey[VIII] was conducted throughout Ontario covering potential areas. (horticulture, agriculture, turf growing, organic farming, hydro seeding, bedding and litter, golf courses, parks and recreation, vineyards, nurseries, green houses, and research stations). It was apparent very early that several areas could consume a

considerable tonnage of compost: eroded and sterile farm acreage, and abandoned gravel pits, mine tailings etc. Being site specific and subject to economic pressures, and legislation, it was decided to leave these applications for the future.

Our interest then was to establish credibility of the product in the multiple uses indicated by our study e.g. areas that make use of soil amendments, soil mixes, and conditioners.

The Macro Study (1976/77) excluding the tonnage uses mentioned earlier indicated a market composed of the following areas of usage:

Parks	- 8%
Horticulture	- 17%
Vineyards	- 8%
Nurseries	- 7%
Garden Centres	- 7%
Mushrooms	- 4%
Bedding	- 7%
Agriculture (organic, turf, seed, etc.)	- 42%

Although a demand of about 120,000 tons was established at that time, in all likelihood, this is closer to 300,000 tons

today (1984) exclusive of course of the aforementioned uses in large tonnage reclamation projects.

From the macro study, we looked at various specific applications as:

Conservation Authorities/ Agencies	Parks, nature and forest preserves, botanical gardens
Municipal Authorities	Parks and Recreation Horticulture Works Depts./Public Buildings Gardens
Nurseries, Garden Centres	Horticulture Supplies Blended Soils Container mixes
Provincial Highway Maintenance	Embankment control Hydro Seeding
Turf Farming	Mulch, Soil Conditioning
Golf Courses	Turf maintenance Soil Conditioning
Manufactures, Wholesalers, Retailers	Blended soil products

Certain decisions had to be made as to the types of compo product offered to the market place. Should we at the F value add to the compost by additional processing or s offer it in bulk form as-is?

We felt additional processing should be left to th sector. The entrepreneur could add value to our t

then market a variety of blended products at a higher dollar value.

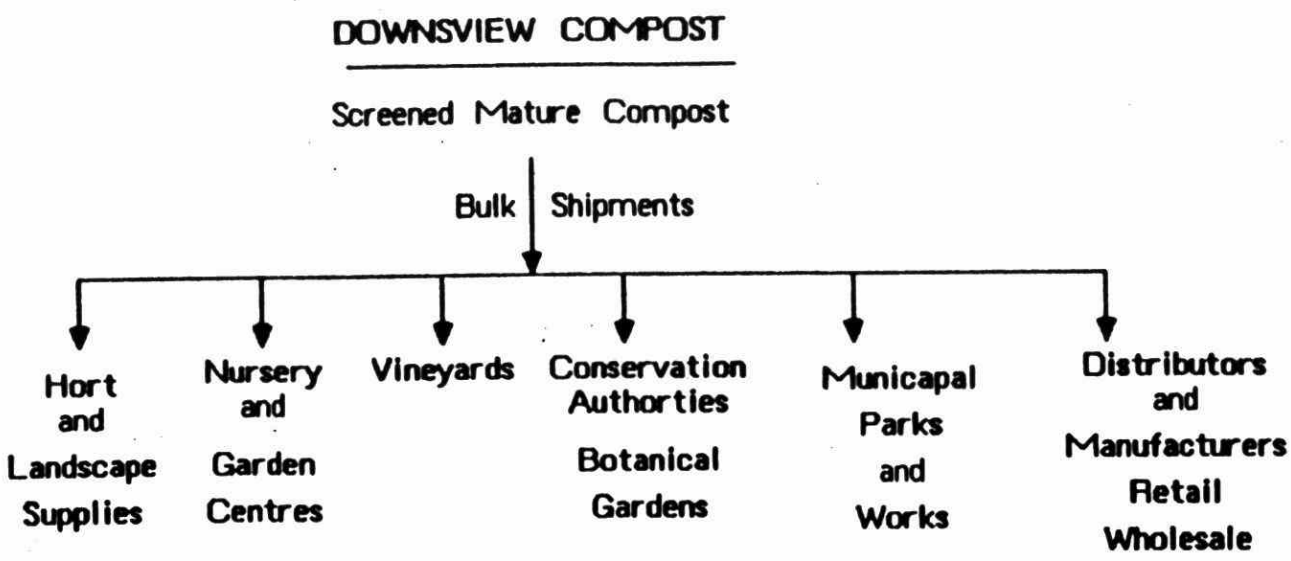
Additional processing could involve drying, pelletizing and granulating and eventually bagging. Nutrients additions to the product could also be done. We already have been conducting some of this development work with several private operators as well as discussing the feasibility of entrepreneurs taking over the marketing of our product.

Marketing our product then to a manufacturer or distributor (wholesale, retail) has been a priority. In addition, we are establishing credibility for compost in the multiple users as listed (Table II).

Market Value

The competetive pressures in the market place for products like compost have been so severe in the past few years that prices have decreased. Established commercial products like peats, screened top soils, various soil mixes, manures make it difficult to establish compost as a viable commercial product. Prices vary considerably. Municipalities with a compost operation may well be content to utilize the product in their area of responsibility; parks, public works, recreation, gardens, etc. and place a value on it relative to

Table XI


DOWNSVIEW COMPOST
Screened Mature Compost
Bulk Shipments
Hort and Landscape Supplies
Nursery and Garden Centres
Vineyards
Conservation Authorties
Botanical Gardens
Municapal Parks and Works
Distributors and Manufacturers Retail Wholesale

the savings in waste disposal. A reduction in land-fill requirements should be part of that consideration. Alternately municipalities could consider marketing the product as-is to a private distribution/manufacturer at a value to cover their net costs and leaving the real product development and marketing to the entrepreneur.

Cost Production

Establishing realistic costs in relation to the exact operational and maintenance costs for composting at the Experimental Plant is difficult, because of the integration of the composting module with the other resource recovery modules. It also shares the costs of most of the other operations. As a separate entity, the composting operation as a single production module, could be made much simpler (preparation and conveyance) and no doubt costs would be lower.

The costs at the E.R.R.P are as follows:

1981/82 Fiscal Year (Table 12)

Without including the related or shared costs of the other E.R.R.P. operations, the cost of producing one metric tonne of organic feed stock through the digester during the year 1981/82 averaged $13.50. The cost during the 1983/84 year

TABLE 12

ERRP COMPOSTING COSTS - 1981-1982

	Cost $ for Year	Cost $ per Tonne Proc.	Cost $ per Produce M.Tonne
I. COMPOSTING MODULE COSTS			
WAGES - BENEFITS	19,102.68	3.08	4.62
OPERATING SUPPLIES	5,606.81	0.90	1.35
ELECTRICITY	10,226.03	1.65	2.47
MAINTENANCE	48,775.55	7.67	11.81
	83,711.07	13.50	20.25
II. SHARED/RELATED COSTS			
SECONDARY SHREDDING, SEPARATION, 1-MAN/R.	16,500.00	2.66	4.00
WAGES, BENEFITS.	19,200.00	3.09	4.64
FRONT END LOADER - 1-YR. 1/2 COST	4,800.00	0.77	1.16
	40,500.00	6.52	9.80
III. TOTAL COMBINED COSTS			
	124.211.07	20.02	30.05

TIPPING FEES - FISCAL YR. 1981-82
TRANSFER STATIONS - $18.50 PER METRIC TONNE
LANDFILL SITES - $10.85 PER METRIC TONNE

TABLE 13

ERRP COMPOSTING COSTS - 1983-1984*

I. COMPOSTING MODULE COSTS

	Cost $ for Year	Cost $ per Tonne Proc.	Cost $ per Produce M.Tonne
WAGES - BENEFITS	20,417.38	4.95	6.68
OPERATING SUPPLIES	95.58	0.02	0.03
ELECTRICITY	9,292.31	2.25	3.04
MAINTENANCE	24,244.00	5.87	7.92
	54,049.27	13.00	17.68

TONNES PROCESSED
4126.80

*EXCLUDING SHARED/RELATED COSTS ASSOCIATED WITH OTHER MODULES.

TIPPING FEES - FISCAL YEAR 1983-84

TRANSFER STATIONS - $23.53 PER METRIC TONNE
LANDFILL SITES - $13.25 PER METRIC TONNE

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was slightly lower (Table 13). Retrofit costs amounted to about $2.00 per metric tonne and should eventually become minimal.

If the composing module shared the costs of the other modules of the E.R.R.P., then the total cost of product organic feed stock would increase to about $20.02 per metric tonne.

This total cost of production could have been reduced during this period by recovering some of the digester discharge oversize material from the post-screening operation. The increased output at least 30% will reduce the cost from $20.02 to about $14.00 per metric tonne.

Through put obviously has a big effect on the costs. Other jurisdiction have reported production costs ranging from $7 per short ton to $18 short per short ton, but with production capacities ranging from 100 tons per day to 400 tons per day.

Revenues

There are 2 sources of revenue; the tipping fee and revenue from compost sales. Credit should also be considered for waste reduction and reduced waste disposal. This has not been done for the data presented here.

Our prices have ranged from $2 per cu. yd. to $10 per cu. yd. ($4.32 to $22 per tonne), but usage is so site specific that there will be some variance in price. Blended compost products in bulk are known to sell for higher prices ($20 to $30 per yard). A private distributor probably is in a better position to do this.

We have been successful in selling our product to a number of users. In so doing, I feel a good part of the mandate has been achieved; i.e., establishing users and product credibility and some value to the product. Plans are to have the E.R.R.P. product handled by the private sector (distribution etc.) in which case, the stage would be set to handle product that may come from a plant built in other areas.

The economics of composting as a waste management option require considerable soul searching, the true value cannot be determined strictly by the profit motive. The social and environmental advantages of composting compared to landfilling waste cannot be ignored.

Although the present status of large scale commercial composting of municipal solid waste and/or waste water sludges is not well established, the fact remains that interest is beginning to mount in this option of waste management.

There are multiple users of organic compost and in additions there are large scale potential applications in the areas of

land reclamation and agricultural lands. We feel the effort of the Waste Management Branch of the Ministry of Environment through the facilities of the E.R.R.P have assisted in the development of composting.

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References

I. Resource Recovery Centre Vol. I - Kilborn Engineering, 1974
Resource Recovery Centre Vol.II - Kilborn Engineering, 1974

II. Fairfield Engineering - Digester Manual, Marion, Ohio

III. Guidelines for Sewage Sludge Utilazation

On Agricultural Lands - Ministry of Environment, March, 1981

Agriculture Canada - Production and Inspection Branch - Trade Memorandum - Fertilizer Act, July 1981.

IV. Compost Engineering - R.T. Haug, Ann Arbour Press

V. Survival of Enteric Bacteria and Viruses in Compost - Compost Science, March/April 29-35, 1979

Cooper and Golveke

VI. Ministry of Environment - Ontario - Laboratory Rexdale, Ontario

VII. Organic Compost - 1982, P.J. Provias, Ministry of Environment

VIII. Market Study - Ministry of Environment, 1966/77

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796.5
.057
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